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THE UNIVERSITY OF ALBERTA

MEMORY FUNCTION IN MULTIPLE SCLEROSIS

BY

PATRICIA NOREEN SHAW

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Memory Function in Multiple Sclerosis submitted by Patricia Noreen Shaw in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Supervisor

Date Feb 20, 1988

ABSTRACT

The purpose of this study was to investigate the memory functioning of a group of individuals with the diagnosis of multiple sclerosis.

One hundred subjects with definite MS were chosen from the list of patients registered at the Multiple Sclerosis Patient Care and Research Clinic located in the Clinical Sciences Building of the University of Alberta, Edmonton, Alberta. Three interviews were conducted with each subject where demographic, disease and IQ information were gathered and a comprehensive memory test was administered.

Statistical analysis of the data revealed that 45% of the sample had poor memory functioning.

The data were further examined to determine whether those patients exhibiting abnormally poor memory had any pattern of memory loss based on the conceptual divisions inherent in the memory test (i.e., modality, content, temporal span, or method of retrieval). No pattern was found, but it was not possible to determine whether this was due to the actual absence of such a pattern or the inability of the test to discriminate.

A path analysis revealed a negative relationship between the severity of the disability due to MS and level of intelligence as measured by a vocabulary test. There was also an independent

negative relationship between the severity of the disease and the level of memory functioning.

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CHAPTER I

INTRODUCTION

The ability to remember is a vital characteristic of humankind and has been essential to their survival from earliest times. The ability to recognize friend from foe, to recall routes to hunting or food gathering areas and to be able to remember technological advances however meager, made it possible for them to survive in a dangerous and precarious environment. Indeed without any functioning memory, independent life would be impossible as one would have to approach each new or recurrent event with the knowledge and skill of a newborn infant.

The existence of even a moderate memory deficit presents many difficulties for individuals in their everyday life. Their inability to remember events, people or facts normally acquired by others, seriously affects their self-concept, their problem-solving ability, their personal relationships, and their employment. Such a memory deficit is seen clinically as a concomitant of multiple sclerosis, often becoming obvious in the advanced stages of the disease to clinicians, but unrelated to the age of the person (Poser, 1981).

Multiple Sclerosis

Multiple sclerosis (MS) is a demyelinating disease of unknown etiology affecting the central nervous system. It is most

commonly found in the north and south temperate latitudes, with southern Canada in general seen as an area of high incidence with 31,000 cases and Alberta with 4,000 cases (Warren, 1986). The disease, which begins primarily in young adulthood, is characterized by various motor and/or sensory changes which tend to exacerbate and remit, with each remission leaving the individual with some residual losses. The course of the disease is extremely variable, almost individual, with some few patients dying within two years of diagnosis and others who may experience up to 20 years between exacerbations. Although the variability of the disease course is characteristic, one can roughly categorize sufferers into one of three groups:

Group I (Remitting) - in this group exacerbations usually are followed by almost complete recovery from symptoms.

Group II (Remitting/Progressive) - these individuals experience some recovery after exacerbation but not to the extent of an absence of symptoms.

Group III (Chronic Progressive) - in this group there is a steady downward progression in the neurological status of the individual with little recovery following exacerbations. A person initially may be in the remitting group in the early stages of the disease but over time, the disease may become more progressive in nature (Brown, Beebe, Kurtzke, Loewenson, Silberberg, & Tourtellotte, 1979).

Just as the severity of the course of the disease is extremely variable, so are the particular disabilities that any one individual may encounter. Some may suffer primarily from motor deficits, others from visual problems, while still others experience cognitive impairment, including memory loss; with some people having to cope with various combinations of all these conditions.

The pathological process which underlies these variable signs and symptoms is the destruction of the myelin sheath, but with preservation of the axonal process of some nerves in primarily the white matter (but also occasionally in grey matter) of the central nervous system (CNS). The resulting "placque" which appears as a "sharply defined, greyish yellow, rubbery, semi-translucent circular or elongated lesion" (Hallpike, 1983, p. 204) interferes with the normal conduction of impulses along the nerve. Although the placques may occur anywhere in the CNS, a very common site in more than 90% of cases is in the periventricular area surrounding the lateral and fourth ventricles. Placques may also be found in the optic tracts, spinal cord, pons, midbrain, and basal ganglia. It is often difficult to localize the area of placque formation from the symptoms displayed and this is only determined absolutely, on post-mortem examination. Although the signs and symptoms of the disease may often appear to wax and wane, it is believed that there is some degree of continuous activity in

placque formation and progression (Hallpike, 1983). In addition, it is thought that as well as the many and varied physical symptoms, the demyelinated cerebral lesions may give rise to personality changes and mental impairment (Ross & Reitan, 1955).

Intellectual Impairment Associated with Multiple Sclerosis

The existence of mental impairment including memory was noted by Jean Marie Charcot (1877), when he first described the disease "blunting in their totality", the intellectual functions of patients. The neurological literature in the early 20th century and until the present decade has downplayed the importance and incidence of cognitive and memory problems in MS as being rare and confined generally to those who have had the disease for a long time and were severely affected physically (Adams & Victor, 1977). As Poser (1984) states "with the possible exception of sexual dysfunction, no area of concern in MS has been more neglected than the neuropsychologic aspects" (p. 15). He suggests that there are several possible reasons why clinicians were less willing to look at cognitive deficits as a distinct possibility, considering the known presence of placques in both cerebral grey and white matter. The evidence from neuropsychological data was seen as "soft data" and therefore less acceptable to neurologists than directly observable motor and sensory deficits. There was also the fear that revealing the possibility of cognitive deficits might be harmful to the patient's ability to cope with a disease process in

which future disability, either in degree of severity or area of affliction cannot be predicted.

In 1921, the report of the authoritative Association for Research in Nervous and Mental Disease stated that mental deterioration was not a concomitant of MS (Dana, 1921). The confusion was further compounded by a study in 1926 (Cottrell & Wilson, 1926) which found that 2% of their MS subjects had disease-related cognitive impairment and another in 1929 (Ombredane, 1929) in which 70% were shown as impaired.

Recent Studies of Memory Function in Multiple Sclerosis

In the last decade there has been increasing interest in this somewhat confusing and neglected area of research. While some studies have examined memory as an integral part of more general cognitive functioning, others have looked at memory in isolation. An examination of recent studies (Beatty & Gange, 1977; Carroll, Gates & Roldan, 1984; Heaton, Nelson, Thompson, Burks, & Franklin, 1985; Rao, Hammeke, McQuillen, Khatri, & Lloyd, 1984) (to be discussed more fully in the following chapter), strongly supports the premise that many MS patients suffer from some degree of memory loss and that this loss is more common than the neurological literature suggests.

It is soon apparent however, that although these studies are provocative, there are also serious methodological problems which diminish their ability to provide an understanding of the memory

deficit in MS; these methodological problems can be summarized under the following headings:

1. Too small a sample. The extreme variability possible in lesion sites and consequent symptoms requires that a reasonably large sample be examined. Some studies have as few as 12 or 22 subjects.

2. Important variables not included. It is important to include all possible demographic and disease variables which may affect the variable being examined, such as the degree of disability, the years since disease onset and the educational level of the subjects.

3. Memory measures not always comprehensive. Often the memory measures examined were only one or two facets of memory, such as verbal or auditory memory. Other studies have not looked at memory variables themselves but rather at the methods or strategies by which we attempt to remember material.

4. Biased sampling procedures. Some samples chosen, were composed of only one distinct group of MS patients such as all ambulatory patients (a minimally affected sample), or all the residents of an extended care facility (possibly a severely affected or elderly sample) or all patients referred as having a cognitive or memory problem (an obviously skewed sample). These groups would of course not provide the range of disability necessary to obtain a clearer picture of the scope of impairment.

5. Exclusion of patients in acute exacerbation. Many studies do not include the information as to whether the subjects were in acute exacerbation or not. These patients in whom the disease process is currently very active, may not represent the general picture of the memory impairment but rather a short-lived deficit due to acute illness.

These methodological problems make useful comparisons between the studies and generalizations to the population of MS patients exceedingly difficult.

Importance of Information on Memory Impairment

Although memory loss can have a devastating effect on the individuals as they try to adjust to the presence of a chronic disease and can directly affect their ability to benefit from a rehabilitative program, we know little about the prevalence and characteristics of this loss.

Many articles and publications on MS do not even mention cognitive deficits, including memory loss, as symptoms although these losses may be more distressing to the individual than the presence of physical symptoms. As Lezak (1983) states "severely impaired memory isolates the patient from emotionally or practically meaningful contact with the world about him and deprives him of a sense of personal continuity, rendering him passive and helplessly dependent. Mildly to moderately impaired memory has a disorienting effect" (p. 25). One can postulate

perhaps, that these areas are largely ignored because of the methodological imperfections and resulting conflicting data in the research or perhaps as Gianutsos and Grynbaum (1982) state "medicine has focussed traditionally on overt disabilities such as motor weakness or incoordination, loss of limb or speech dysfunction" (p. 37) and intellectual deficits have not been given sufficient attention by clinicians. However, in order to more fully understand the disease, its effect on cognitive functioning and specifically memory, needs to be documented.

Of equal importance to the need to contribute to the general body of knowledge of the disease process and its effects, is the essential function of assessing the strengths and weaknesses of the person who is trying to adjust to this disease. In the psychological assessment of the individual patient the most useful first step is the systematic assessment of memory (Walsh, 1978). In order to understand what problems individuals are having to deal with and to estimate their level of coping ability, it is vital to know whether their memory function is intact or not.

When designing a physical rehabilitation program for the individual the knowledge of any specific area of memory loss would enable the clinician to use intact areas and avoid areas of weakness. For example, if one were teaching the steps in transferring from wheelchair to bed and the individual was weak in auditory verbal memory, one would be able to teach most

effectively using diagrams rather than spoken verbal instructions. If it was known that a patient had a generalized memory loss the physiotherapist or occupational therapist would be aware of the need for repetition, increased cues, etc. rather than believing the patient was either disoriented, uncooperative or unable to learn.

There is currently an increased interest in the remediation of memory itself with individuals who have suffered memory loss from disease or trauma. These techniques may also be useful with MS patients. In order to remediate memory, one would first need to determine whether there was a generalized memory deficit or to delineate specific areas of loss in order to design strategies for remediation of patients coping with this problem.

Purpose of the Study

The present study was designed to provide much needed, information about memory loss and its prevalence in patients with MS by the use of a theoretically and clinically relevant memory assessment battery. By the inclusion of relevant demographic and disease data, as well as choosing a reasonably large sample and the exclusion of any subject currently in exacerbation, an attempt will be made to overcome some of the methodological shortcomings of previous studies.

Present Study

One hundred subjects were randomly chosen from the list of patients registered with the Multiple Sclerosis Patient Care and Research Clinic at the University of Alberta Hospitals. The Western Multi-dimensional Memory Battery (a comprehensive test of 24 memory variables) and the Peabody Picture Vocabulary Test-Revised (a measure of receptive vocabulary closely related to general intelligence) were administered. The Kurtzke Disability Scale and the Kurtzke Functional Systems Scale (rating scales of neurological deficit) were obtained following examination by a neurologist. Each patient's disease course was also classified as being in the category of either Remitting, Remitting/Progressive or Chronic Progressive by a neurologist (Dr. K. G. Warren). Demographic information on sex, age, marital status, educational level, estimated IQ level, occupation, and employment status was also recorded. The number of years since onset and diagnosis completed the information collected on the disease course. This information was compared to that collected for a normative sample (ref; see The Normative Group, Chapter 3).

Research Hypotheses

1. There is a significant difference between the memory functioning of the MS group and a normative sample (to be described in Chapter 3).

2. There will be a pattern of memory deficit common to those subjects who are judged to have significantly abnormal memory.

3. There will be a relationship between memory functioning and demographic factors, disease measures and intelligence in the MS group.

Definitions

MS	- Multiple Sclerosis; a demyelinating disease of the central nervous system
CNS	- Central Nervous System; the brain and spinal cord
Myelin	- a fat-like substance forming a sheath around certain nerve fibres believed to influence the rate of conduction of the nerve impulse
Demyelinate	- to destroy or remove the myelin sheath of a nerve or nerves
Exacerbation	- an acute increase in the severity of old or the appearance of new symptoms
Remission	- the improvement or abatement of symptoms; in MS it may represent a complete absence of symptoms or merely sustained improvement following exacerbation

Clinically Definite MS - because there is no laboratory test which will confirm the diagnosis of MS, the patient must fulfill the Schumacher (1965) criteria to be judged as having clinically definite MS (see Appendix C, Schumacher Criteria (1965)).

CHAPTER II

REVIEW OF THE LITERATURE

> Now let us turn to the treasure house of inventions, the custodian of all parts of rhetoric, memory.
>
> Cicero: DeOratore, Book I

Although the subject of memory has been of interest to philosophers since before the 4th century BC, Hippocrates is credited with the "physicalization" of memory which made possible the development of theories which are the forerunners of today's structural models (Marshall & Fryer, 1978). He believed that memories were objects with size and which occupy space and can be stored.

Historical Beliefs about Memory

Plato (427 - 347 BC) further developed this concept when he had Socrates describe to Theaetetus the method by which memories are laid down.

> Soc. I would have you image then, that there exists in the mind of man a block of wax, which is of different sizes in different men; harder, moister, and having more or less purity in one than another, and in some of an intermediate quality.
>
> Theaet. I see.

Soc. Let us say that this tablet is a gift of Memory, the mother of Muses; and that when we wish to remember anything which we have seen or heard, or thought in our own minds, we hold the wax to the perceptions and thoughts, and in that material receive the impression of them as from the seal of a ring; and that we remember and know what is imprinted as long as the image lasts; but when the image is effaced, and cannot be taken, then we forget and do not know. (p. 359)

Later in the same dialogue he uses another metaphor to foreshadow the concept of both storage and retrieval.

Soc. One more, then, as in what preceded we made a sort of waxen figment in the mind, so let us now suppose that in the mind of each man there is an aviary of all sorts of birds - some flocking together apart from the rest, others in small groups, others solitary, flying anywhere and everywhere.

Theaet. Let us imagine such an aviary - and what is to follow?

Soc. We may suppose that the birds are kinds of Knowledge, and that when we were children,

this receptacle was empty; whenever a man has gotten and detained in the enclosure a kind of knowledge he may be said to have learned or discovered the thing which is the subject of the knowledge and this is to know. (p. 542)

Still later he described the possibility of error in retrieval.

Soc. ... in no case can a man not know that which he knows, but he may get a false opinion about it; for he may have the Knowledge, not of this particular thing but of some other; ---when the various numbers and forms of Knowledge are flying about in the aviary and wishing to capture a certain sort of knowledge out of the general store, he takes the wrong one by mistake, that is to say, when he thought eleven to be twelve, he got hold of the ring dove which he had in his mind, when he wanted the pigeon. (p. 543)

Aristotle, the student of Plato, using the concept of the tabula rasa develops the idea of individual differences in the ability to remember.

The process of movement involved in the act of perception stamps in, as it were, a sort of impression of the percept, just as persons do who make an impression with a seal. This explains why, in those

> who are strongly moved owing to passion, or time of life, no mnemonic impression is formed; just as no impression would be formed if the movement of the seal were to impinge on running water; while there are others in whom, owing to the receiving surface being frayed, as happens to the stucco on old chamber walls or owing to the hardness of the receiving surface the requisite impression is not implanted at all. Hence both very young and very old persons are defective in memory; they are in a state of flux, the former because of their growth and the latter owing to their decay. In like manner, also, both those that are too quick and those who are too slow have bad memories. The former are too soft the latter too hard in the texture of their receiving organs so that in the case of the former the presented image though imprinted does not remain in the soul while on the latter it is not imprinted at all. (p. 691)

He also describes the importance of organization.

> Accordingly, things arranged in fixed order, like the successive demonstrations in geometry are easy to remember or recall, while badly arranged subjects are remembered with difficulty. (p. 693)

Finally, he anticipates the work of Conrad (1964) and

Wickelgren (1965) on acoustic confusions in short-term memory with this example.

> This last consideration explains too how it happens that, when we want to remember a name, we remember one somewhat like it, indeed but blunder in reference to [in pronouncing] the one we intended. (p. 694)

While the ancient Greeks were more given to metaphor and introspection than current researchers whose interest is in quantification and experimentation, the most important fact remains that their basic ideas of the structural nature of memory are relatively unchanged to the present day. Moderns have added methods of measurement, elaborations and testable hypotheses but only as refinements of the ancients ideas. As Marshall and Fryer (1978) point out although "we have now collected far more facts about memory than were available to the Greeks, it is less clear that any new theories have been put forward in recent years" (p. 20).

In the centuries following the Greek philosophers, although memory was an area of interest, particularly in the study and use of mnemonics, it was not until the 17th and 18th centuries that British Associationists building once again on the work of Aristotle, developed these ideas into a set of laws of association as an explanation for the acquisition and retention of knowledge. Although there appears to be some substance to the idea that

things which are similar and occur close together in time, will be remembered together, this fails as an explanation in physiological terms at a time when brain physiology was of great interest. The rapid growth of knowledge of neural anatomy and physiology in the late 19th century permitted speculation about the localization of memory in the brain, the nature of the nervous impulse and its relationship to the memory "trace" (Murray, 1980).

The scientific study of memory began only in the late 19th century with first, the publication of Ribot's "Diseases of Memory" (1882) and then three years later the experimental studies of memory by Herman Ebbinghaus (1885). Ebbinghaus is generally credited with being the Father of the Scientific Study of Memory for his attempt to introduce order, experimental control and scientific objectivity.

Since that time, there have been three major thrusts in the analysis of memory. Firstly, the experimental study of intact memory following the traditions of Ebbinghaus which has produced a tremendous number of experiments, research papers and theoretical models examining an almost infinite variety of phenomena related to memory. Although as Eysenck (1977) points out this "enormous recent proliferation of articles and books on human memory does not necessarily imply a commensurate increase in knowledge" (p. 1). There is, as yet, little agreement on the principles of basic memory functioning and one finds a plethora of contradictory

studies, opinions and models (Baddeley, 1978; Eysenck, 1977; Schacter & Tulving, 1982; Tulving & Madigan, 1970).

Secondly, the study of abnormal memory or the amnesias, has progressed largely in parallel to the experimental study of memory, with little cross-fertilization between the two approaches until very recently (Schacter & Tulving, 1982). The study of amnesia is basically a clinical approach, using case studies of individuals who suffer a memory deficit from disease, aging, trauma, or surgical procedures and who are subjected to a few restricted areas of experimental investigation. The main thrust of the research on amnesia, has been to identify patterns of memory loss that are specific to a particular disease or syndrome.

The third area of interest in memory research is the investigation of memory in a naturalistic context such as in eyewitness memory (Loftus & Palmer, 1982), flashbulb memories (Brown & Kulik, 1982) and reports of the skills of mnemonists (Hunter, 1977; Luria, 1968) etc. Although this is a fascinating area of research, this present study will be confined to a blending of the first and second avenues of memory research only. Due to the wealth of research in even these two fields it is nessary to restrict the following discussion to a very selective examination of the literature on memory.

Models of Memory

The Structural Model

In the 1950s, psychologists became interested in trying to elucidate a model of memory that would specify the structures, component operations and the order in which information would be processed. Two early attempts (Broadbent, 1958; Waugh & Norman, 1965) were followed by the Atkinson and Shiffrin model in 1968 which is generally accepted as the most sophisticated and comprehensive one available for adherents of the structural model of memory. This model consists of three basic permanent structural features: the sensory register, the short-term store and the long-term store. Information received through the sense organs is held very briefly (several hundred milliseconds) in the sensory register and then, that which is not attended to, is lost by decay. Atkinson and Shiffrin (1968) posit modality specific divisions for this register, such as visual, auditory, kinesthetic, etc. Only that information which has been selected for attention will be transferred to the short-term store, where it is thought to exist in an auditory verbal linguistic form or possibly in other modalities for a matter of less than 15 - 20 seconds. Information which is not rehearsed will be lost by displacement from new incoming information to this store. Rehearsed information may then enter long-term store (which they believe to have infinite capacity), and is lost chiefly through

interference from subsequent or previous information. They also suggest that information may go directly from the sensory register to long-term store and that there is a reciprocal flow, both in and out of long-term store and short-term store.

As well as these permanent structural features, they also discuss control processes which are seen as not permanent and as being under the control of the individual. These include selective attention, strategies of storage, search retrieval, and rehearsal. These control processes are used to select the information to be processed, to determine how it will be stored and methods used to retrieve it.

The foregoing description is, of course, a severe oversimplification of the Atkinson and Shiffrin (1968) model and most researchers feel that the model itself is an oversimplification of the operation of human memory (Baddeley, 1981; Eysenck, 1977). Perhaps its greatest contribution is as a basis for discussion and experiment, because not all aspects of the model have been upheld by subsequent research. For example, the model's assertion that material is coded phonemically, in short-term store and semantically, in long-term store, has not been supported by experimental confirmation (Bruce & Crowley, 1970; Glanzer, Koppenaal & Nelson, 1972; Gruneberg & Sykes, 1969).This inadequacy in process delineation, however, is less important than the premise that memory is structural and

multi-store in nature. Additional evidence for the presence of two memory stores (the duplex theory) comes from a study by Glanzer and Cunitz (1966) where using free recall, they found differential effects on the recall of the initial list items (primacy effect) and last list items (recency effect). They found rehearsal improved primacy but not recency, whereas a distractor task adversely affected recency, but primacy was unaffected. It is thought that the recency effect reflects information in short-term store and the primacy effect is due to long-term storage.

Those researchers who accept this basic structural model have generated several refinements to the model such as Baddeley's (1981) concept of short-term memory as "working memory" with its three components--the Central Executive which selects and operates the control processes, the Articulatory Loop which is able to maintain verbal rehearsal and the Visuo-Spatial Scratch Pad which operates the rehearsal of visual material using visual spatial imagery.

The clinical study of the amnesias also offers support for the multi-store model of memory and as Waugh (1969) asserts "it is almost axiomatic that one can learn as much about a system by studying its failures as by describing its successes" (p. vii).

Wickelgren (1973) cites the evidence from the literature on amnesia for a dual memory system from case studies of individuals

who have normal verbal, short-term memory and an inability to retain material in long-term memory. Other patients appear to have an intact long-term memory but are unable to place auditory and visual material into short-term memory (Warrington & Rabin, 1971; Warrington & Shallice, 1969).

There is also evidence that deficits may be modality specific; for example, a patient who could apprehend verbal visual information and transfer it to long-term store was unable to perform the same transfer when the same verbal material was presented auditorily (Shallice & Warrington, 1970; Warrington & Shallice, 1969, 1972). Deficits in amnesia may also be material specific in that nonverbalizable material may be retained while verbal material is not and vice versa. Patients with left temporal lesions are likely to suffer a verbal deficit (Butters, 1979; Corsi, 1965; Gerner, Ommaya & Fedio, 1972) while individuals with disease or trauma of the right nondominant hemisphere will have more difficulty with nonverbalizable material (Corkin, 1965; Kimura, 1963; Milner, 1965, 1968).

The Process Model

Of course, not everyone accepts the structural model of memory and one of the most seminal contributions in this area has been the process model of Craik and Lockhart (1972). They believe that incoming information, instead of being placed in two stores of varying characteristics, is processed to various levels or

stages. These range from physical analysis (shallow), to phonemic analysis (moderate) to semantic analysis (deep), with retention increasing with the depth of processing. Type I processing, which appears to be similar to the concept of rehearsal (Atkinson & Shiffrin, 1968), maintains information by recycling at a given level. Type II processing requires that the information be further processed to a deeper level. Their model attempts to address some of the problems that are seen in the structural model. These include discrepancies in the experimental studies on the capacity of short-term store (Baddeley, 1970), the problem of whether verbal material may also be stored semantically in short-term store (Shulman, 1970, 1972) and the inconsistent results obtained in studies looking at the durability estimates of the memory trace (Kroll, Parks, Parkinson, Bieber, & Johnson, 1970; Neisser, 1967).

Although these problems with the structural model cannot be ignored, there has been even more severe criticism of the process model itself. There exists at present no method for defining or independently measuring the "depth" of the processing when one examines the argument logically, it becomes somewhat circular. Craik and Lockhart's assertion that Type I processing (rehearsal at the same level) will not result in a stronger memory trace has been disconfirmed (Baddeley, 1978; Nelson, 1977). The model also fails to explain some of the data from amnesia studies such as

when an amnestic subject is able to carry on a normal conversation (presumably "deep" semantic processing is required) but is unable to retain the trace in new long-term memory (Baddeley, 1976). Indeed, Wickelgren (1981) in his review of human learning and memory states that "the levels of processing fad is over in the field of learning and memory" (p. 11). A less extreme view is suggested by Seamon (1980) in which he attempts to combine both structure (Atkinson & Shiffrin, 1968) and process (Craig & Lockhart, 1972) models in one unified system in which "information is conceptualized as existing in short-term or long-term storage with the rate of transfer from short-term to long-term storage a function of the depth of processing" (p. 133).

While acknowledging the existence of shortcomings in the Atkinson and Shiffrin (1968) model, the theoretical basis underlying the following research will be a combination of the structural model with clinical evidence from studies on amnesia. When an attempt is made to combine the theoretical formulation with this clinical evidence the resultant model is a multi-store model which has to accommodate material specific (verbal or nonverbal), modality specific (auditory, visual) and temporal (long-term store, short-term store) aspects and all possible combinations of these factors.

Assessment of Memory

Importance of Memory Assessment

As mentioned in Chapter I, it is essential to obtain an accurate picture of the memory problems that individuals with MS may be experiencing in order to more fully understand their difficulties in coping daily with a chronic disability. To design rehabilitative strategies that will enable them to achieve optimum adjustment, one must be able to identify strengths and capitalize on them while avoiding areas of weakness. If treatment is being given, either chemical or cognitive retraining, it is necessary to establish a baseline of memory performance in order to ascertain the effectiveness of the therapy (Mayes, 1986). A comprehensive examination of memory would contribute not only to these three purposes but also provide information about the nature and degree of memory dysfunction that occurs in MS.

Difficulties in Memory Assessment

It is axiomatic that underlying each valid psychological test there is a construct or theoretical basis acceptable to the majority of experts in that field. Unfortunately there is no such universally acceptable theory of memory and the tests available to examine memory either lack a theoretical basis or attempt to examine some discrete area of functioning with little endeavor to be comprehensive (Erickson & Scott, 1977).

When examining the nature of deficits possible in memory dysfunction, one is almost overwhelmed by the tremendous variability. Some examples follow. If the frontal lobes and the reticular formation are affected the individual will have difficulty sustaining attention or perhaps in organizing strategies to enhance recall (Luria, 1973). Access to old semantic memories and the acquisition of new information can be jeopardized by damage to the posterior association cortex (Warrington, 1982). The organization of new information into a previously formed structure depends on the unhampered operation of the hippocampus, the medial thalamus, and the frontal lobes (Roth & Crosson, 1985). Lateralization of verbal memories in the left hemisphere and visual memories in the right hemisphere (in right-handed persons) (Russell, 1975) requires that any comprehensive test of memory would include both verbal and visual components. These few examples of the evidence from studies of memory deficits subsequent to brain damage from trauma or disease underscore the difficulty in producing a test which would examine all or even a few of these areas.

Another source of difficulty in memory test construction is the need for a test that is reasonably convenient to administer to the subject. Whether the test will be used for research or by the clinician, the subject and his comfort must always be considered. To incorporate all the known elements of memory in the test would

prove too unwieldy, fatiguing and time consuming, therefore, it is necessary to select only the most vital components.

The Wechsler Memory Scale (1945)

It is surprising that with the current interest and rapid development in psychometric testing that the test still most widely used to assess memory, is the Wechsler Memory Scale designed in 1945 before the advent of the current theoretical models. As Piersma (1986) notes "there are few tests that have been as frequently criticized, yet as widely used" (p. 323).

This scale is one of a very few tests of memory which even attempt to assess several aspects of memory functioning but is weighted much too heavily toward short-term verbal recall. It has only one visual recall test which can be converted rather easily, by the subject, to verbal recall. Erickson and Scott (1977) also point out that the test is not based on any careful delineation of the construct of "memory" but rather on a loose common sense definition and may even be a better measure of learning than of memory. It may indeed be measuring brain pathology rather than memory per se (Russell, 1981). Prigitano (1978) noted that there were no scaled or standard scores for the subtests and no norms for a large representative sample available. Perhaps the most serious flaw in the entire test is the supposition that memory is unitary, with verbal and visual functions being additive (Dujovne & Levy, 1971). The test may be useful in discriminating between

left or right hemispheral damage (Bornstein, 1982; Russell, 1975) but is inadequate (too coarse and outdated) for a full examination of the multidimensional nature of memory (Shacter & Tulving, 1982).

The test which will be used in this study (The Western Multi-dimensional Memory Battery) attempts to address the shortcomings of the Wechsler Memory Scale noted above. It recognizes the current theoretical position that memory is multi- rather than uni-dimensional and examines the two most common modalities (auditory and visual), content (verbal and non-verbal), temporal (immediate, short- and long-term), and both recognition and recall, with all possible combinations of these variables. The 24 discrete score categories generated for each individual can then be compared with the normative group to look for significant differences on these individual tests.

Recent Studies of Cognitive and Memory Function in Multiple Sclerosis

Although for more than 70 years clinicians have frequently observed apparent cognitive and memory deficits in some of their patients, the research in this area has been contradictory and confusing (Trimble & Grant, 1982). This confusion has been not only with regard to the specific nature of the deficits but even to their degree and prevalence. The methodological problems thought to be responsible for the conflicting data include

sampling problems where either too small a sample to accommodate the variability of the disease or biased samples of individuals of only one level of physical impairment are included. Often, important variables such as the degree of disability or the length of time since onset of the disease are not included and this lack makes comparisons of studies impossible. The instruments used to measure memory have not been comprehensive and often, only one facet of memory is tested although current memory theory suggests that memory is multi-faceted and may be differentially affected by trauma or a disease process. Finally, many otherwise interesting studies have failed to reveal whether they have excluded patients in acute exacerbation where it would be difficult to sort out permanent cognitive and memory deficits from those produced by temporary, acute, physical illness.

Studies Examining General Cognitive Function in Multiple Sclerosis

Researchers in the late 1960s and 1970s began to examine general cognitive function of MS patients including some tests of memory. Jambor (1969), Surridge (1969), and Staples and Lincoln (1979) found intellectual deterioration including memory deficits in many of their subjects and considerable variation in specific areas of loss. These three studies are particularly interesting in that they compared their MS subjects to controls with a different chronic disabling disease to control for the possible

effects of chronic illness such as emotional changes or social deprivation, in producing intellectual deterioration. Three studies of the same period (Goldstein & Shelley, 1974; Ivnik, 1978a, 1978b; Marsh, 1980) found little intellectual deterioration in their samples of MS patients across time. Unfortunately all these studies exhibit one or several of the methodological problems discussed previously.

Peyser, Edwards, Poser, and Filskov (1980) examined the cognitive function of 55 individuals with the diagnosis of MS for a comparison with physicians' ratings of intellectual impairment. Using a modified Halstead Category Test (Leli & Filskov, 1979) and the vocabulary, comprehension and similarities tests of the Wechsler Adult Intelligence Scale (1958) they found 54.7% of the sample fell in the impaired range. They also found that specialized psychological testing was more sensitive to impairment than a general neurology examination. Their impaired patients "were both above and below the mean of neurological involvement" (p. 579) and often had low Kurtzke scales (a test of physical disability) suggesting that cognitive impairment may occur early in the disease course.

An interesting study by Brooks, Leenders, Head, Marshall, Legg, and Jones (1984) looked at the rate of oxygen utilization by means of position emission tomography of the cerebrum and found that oxygen utilization by their 15 MS patients (in remission) was

significantly less than for a group of normal controls. Psychometric tests of general cognitive function as well as verbal and visual memory tests revealed "significant deterioration of cerebral function in 31% of our multiple sclerosis patients" (p. 1191), all of whom had evidence of generalized cerebral atrophy on their Computed Tomography brain scans. There was a significant correlation between loss of premorbid levels of cognitive functioning and lower utilization of oxygen. Specific functions such as memory perception and word fluency showed an even higher level of impairment (54%) than general IQ (31%).

In an excellent study by Heaton, Nelson, Thompson, Burks, and Franklin (1985) an attempt was made to address the major methodological problems. One hundred clinically definite MS patients divided by neurologists' ratings into chronic progressive and relapsing remitting groups, were given comprehensive neuropsychological tests and compared to a large normal control group. The relationship between their scores on these tests and age, disease duration, degree of physical disability, as well as medications being administered was examined. In order to separate the sensori-motor (often impaired in MS) from the cognitive component, the tests were divided into three groups of (a) cognitive tests with minor sensori-motor requirements, (b) cognitive tests requiring a substantial sensori-motor requirement and (c) tests solely of a sensori-motor nature. The comprehensive

battery of tests included were the WAIS (Wechsler, 1958), the Halstead Reitan Battery (Reitan & Davison, 1974) and to examine adaptive abilities, the Grooved Pegboard and Hole-Type Steadiness Tests (Reitan & Davison, 1974), the Wisconson Card Sorting Test (Heaton, 1981), and the Thurstone Word Fluency Test (Thurstone & Thurstone, 1962). Memory was examined by the Tonal Memory Test (Milner, 1967), a modified Reitan's Story Memory Test and the visual reproduction component of the Wechsler Memory Scale (Heaton, Chelune & Lehman, 1978).

They found that the relapsing remitting group was minimally impaired cognitively (33% of group was impaired) whereas the chronic progressive group was impaired on all domains examined (cognitive sensory and motor) (98% of group was impaired) and both groups were significantly affected compared to the normative group. The course of the disease (relapsing remitting versus chronic progressive) appeared to be more significant than the duration of the disease. Medication did not appear to be significant in determining scores. By separating the test battery into cognitive and sensori-motor components they were able to state that cognitive impairment is largely independent of the degree of physical disability and that "MS patients who have a chronic progressive disease course are particularly likely to show significant cognitive limitations" (p. 109).

Recent Studies Examining Memory Function in Multiple Sclerosis

A 1977 study by Beatty and Gange undertook to examine the perceptual-motor and/or cognitive functioning of 26 subjects with a diagnosis of MS. Two tasks were specifically designed to examine encoding, storage and retrieval of information. The subjects performance was compared to a matched control group and there were consistent correlations between motor and memory performance in the MS group but not in the controls. This suggests that although persons with MS may be able to use stored verbal material (as their verbal conceptualization was unimpaired) the processing of new material is disrupted consistent with the degree of motor impairment. The magnitude of their impairment actually increased on subsequent trials and it was not possible to differentially attribute the deficits to consolidation, storage or retrieval of new information or to difficulties in sustaining attention. Although this study is interesting there is no accurate information on the degree of physical disability as we are only told that 24 out of 26 subjects are ambulatory suggesting a relatively small and intact group of subjects from whom it would be difficult to generalize to the larger group of MS patients. The fact that memory deficits exist even in this relatively intact group with only two memory facets examined is suggestive of a more severe and pervasive problem than the general literature implies.

Grant, McDonald, Trimble, Smith, and Reed (1984) confirmed with their study what is now being accepted, at least in the research area, that MS patients have memory deficits and that they occur relatively early in the disease course. They examined 43 patients (50% had had the diagnosis less than five years). Only 31 of their sample had a diagnosis of definite MS, one had early progressive disease and unfortunately 11 patients of the total sample were only "probably" MS This group was compared to a "healthy" group comparable in age, sex and estimated IQ. They were administered the WAIS vocabulary (Wechsler, 1955) (highly correlated with overall intelligence) and the Trail-Making Test (Reitan, 1958) requiring "motor speed as well as the ability to order symbols presented in a visual array" (p. 274). The verbal learning and delayed recall test and the visual learning and recall test of the Wechsler Memory Scale (Wechsler, 1945) and the Brown-Peterson Test (Peterson & Peterson, 1959) (a distractor task which examines short-term memory) were also given. Their subjects, although relatively early in terms of disease course, had deficits in short-term memory, as well as learning and recall of both verbal and non-verbal information. Medications such as ACTH and steroids did not appear to be correlated with memory problems. Memory deficits were correlated with years since diagnosis, irrespective of whether the person was in exacerbation or not, or their age and educational level.

Carol, Gates and Roldan (1984) examined some of the processing aspects of memory. The purpose of their study was to determine whether perceptual memory (encoding of physical properties only) is intact in MS and whether MS subjects can encode information semantically (for meaning) if strategies are forced by the task. They also examined whether subjects would use strategies if they are available but their use was not forced. Their subject group of nine males and 13 females "represented a wide range of disease severity" (p. 298) although they did not give the specifics of the subject's disabilities. Their performance was compared to a matched group of controls.

The perceptual and semantic tasks consisted of studying pictures and later identifying those seen previously from a group of both "old" and "new" pictures. The depth of processing was controlled by having some pictures with a small inked cross (shallow processing) and some in which the subject had to decide whether the object could be picked up and carried (deeper processing). The verbal recognition task consisted in recognizing previously seen printed words from among old and new word cards. The words presented could be grouped into nine categories (e.g., birds) and there was one set of nine unrelated words. The subjects were asked to use any strategy they could to remember the words and to describe it later if they had developed one.

Although MS subjects were similar to the control group in that the forced deeper processing correlated with better recognition, overall they remembered fewer pictures than the control group. Fewer MS subjects reported the use of a strategy to remember than did the controls and even those who reported such a strategy were poorer at recognition, in fact, it appeared that the use of a strategy led to greater confusion between old and new words for the MS subjects. It appears that when semantic coding is optimal it is less likely to be employed by MS subjects and may even lead to "inter-item semantic encoding confusion" (p. 301). The authors point out that this deficit appears specific to MS as other types of amnestics experience both inter-item (relational processing) and intra-item (individual item processing) encoding deficits. This study is interesting because, although the sample is small and disease information is lacking, it is one of the few to examine memory from the process perspective.

Rao, Hammeke, McQuillen, Khatri, and Lloyd (1984) looking at memory disturbance in 44 chronic progressive MS subjects addressed the following areas: (a) Do chronic progressive MS subjects have deficits in immediate and delayed memory compared to controls?, (b) Is this deficit uniform among all patients?, (c) Can this deficit be attributed to CNS disease as opposed to medication, motor or psychosocial problems?, and (d) Is the deficit similar to other amnestic or dementing conditions?. The MS group consisting

of 29 females and 15 males, all diagnosed as chronic progressive according to the Schumacher criteria (1965) (see Appendix C), with a Kurtzke (1983) range of 4 - 9, and with a diagnosis established six to seven years previously. Their results were compared to a patient control group with chronic back pain and a normal control group of hospital employees and relatives. The memory test battery consisted of two experimental measures of verbal and nonverbal memory and the Wechsler Memory Scale (Wechsler, 1945). Additional neurophysiological and personality tests were also given. The MS group when compared with the patients and normal controls, showed impairment in retention and retrieval of both verbal and spatial material with the spatial component being most affected. The performance of the MS group was more variable than the other groups and they felt that this was consistent with the post-mortem findings that not all MS patients experience cerebral involvement by placque formation. They identified using cluster analysis, three groups of MS patients with varying degrees of memory deficits. An unusual finding was that the degree of memory deficit was unrelated to length and severity of illness. Medication was not a significant factor.

Summary of Recent Research of the Association Between Memory and Multiple Sclerosis

The quality of the very early studies is mixed, however, the most recent studies are attempting to correct these shortcomings.

Nearly all the studies of reasonable quality which have evaluated memory have found deficits. By comparing the MS subjects to both non-MS patient and normal control groups and by a careful delineation of tests, they have virtually ruled out the possibility that the memory deficits are due to medication, restricted lifestyle, psychosocial problems, or solely motor deficits. Some studies have examined apparently intact subjects early in their disease course while others have looked at the chronic progressive population. Various small areas of memory functioning have been examined but no study has attempted to examine memory for modality, content, temporal span, and type of retrieval in accordance with the model of structural memory. The following study should be a useful addition to this literature because it includes not only the full spectrum of MS patients but also attempts a more comprehensive examination of their memory.

CHAPTER III

METHOD

Subjects

The sample was chosen from the list of patients registered at the Multiple Sclerosis Patient Care and Research Clinic. The clinic, established in 1978, is located in the Clinical Sciences Building of the University of Alberta, Edmonton, and serves the population of MS patients living in northern Alberta. There are approximately 1,500 patients registered, which probably represents 85 - 90% of the individuals with multiple sclerosis in northern Alberta (Warren, 1986).

One hundred and sixty subject's (male and female) were randomly chosen from the clinic's list once they met the following characteristics:

1. Age range: 15 - 55 years (upper limits chosen to control for the confounding effects of age on memory)
2. Educational level: Grade 7 (minimum)
3. Diagnosis by a neurologist: clinically definite MS
4. Duration of disease: greater than one year since diagnosis
5. Sufficient vision and hearing to participate in the tests
6. Not currently ill or in acute exacerbation
7. Residence in Edmonton, St. Albert or Sherwood Park.

Rejection from the Study

From the names randomly chosen from the clinic's list, 19 could not be contacted as they had either changed their residence or had left the area. One hundred and thirty-five initial phone contacts were made before 100 suitable subjects had agreed to participate. The reasons for refusal or rejection were as follows:

Do not wish to participate	17
Vision too poor	6
Demented	3
Unable to communicate verbally	2
Diagnosis recently in doubt	2
Deceased prior to testing	2
Emotionally upset	1
Non-English speaker	1
Acutely ill at time of contact	1
	35

The Normative Group

The Western Multi-dimensional Memory Battery (WMMB) was normed originally on a group of 304 subjects. This was a representative sample of the residents of London, Ontario, who responded to advertisements in various media asking for volunteers. An attempt was made to obtain a stratified sample with equal numbers of subjects in the various age decades. There

were 135 males, 169 females and the age range was 14 - 74 years. Their IQs were in the normal range (Dr. D. Evans, personal communication, March 7, 1986).

Description of the Instruments Used

Peabody Picture Vocabulary Test - Revised Form

While this well known test is not a comprehensive measure of intelligence, it is an adequate to excellent measure of vocabulary acquisition (Wiig, 1985). Vocabulary is generally considered to be the best single measure of general intelligence (Lezak, 1983; Terman & Merril, 1937; Zimmerman & Woo-Sam, 1973) and tends to be a stable test in adult brain damage (Golden, 1979). Because of the interrelationship between memory ability and intelligence, this measure of cognitive functioning may help to distinguish between memory deficits due to the disease process and those more associated with low premorbid intellectual functioning. It has the added advantage for the MS population that it is appropriate for moderate visual and/or motor impairment which is a frequent symptom of the disease. It is less threatening for the subject than other tests of intelligence and its short administration time did not substantially add to the necessary energy output of the subjects who were expected to undergo a total of more than six hours of testing.

The median coefficient of internal consistency for Form L was .821. The test-retest reliability results in a coefficient of

stability with a median value of .78 (Mitchell, 1985). The authors of the test (Dunn & Dunn, 1980) make the observation when discussing the validity of the test, that it correlates most highly with other measures of vocabulary (.71) and moderately well with other tests of verbal intelligence (.64), such as the Wechsler Adult Intelligence Scale and the Stanford Binet.

Kurtzke's Neurologic Impairment Rating Scales (Part I - Disability Status Scale (EDSS)) (Kurtzke, 1983)

The EDSS is an instrument in common use in both MS rehabilitation and research, that is based on scores obtained from neurologic examination by a physician. It was revised and expanded in 1983 to make it more sensitive to changes in physical status in the middle ranges. The scale allows the categorization of a patient on a 20.0 point scale of disability, ranging from 0 "normal neurologic exam (all grades 0 in Functional Systems (FS) (to be discussed next), Cerebral grade 1 acceptable" to 10.0 "death due to MS". The author prefers to treat it as an ordinal scale although it has a reasonably Gaussian distribution. The EDSS permits comparisons of large groups of patients according to the degree off severity of the disease or a record of the progress of the disease in one patient, over time. It has been developed and refined in order to develop a neurologic impairment rating scale which would be acceptable internationally in MS research.

Kurtzke's Neurologic Impairment Rating Scales (Part II - Functional Systems Rating (FS))

The second part of the rating system consists of eight functional groupings where an individual is graded according to the degree of dysfunction in each system. Only objectively verifiable signs rather than symptoms are included. The functional systems recorded are:

1. Pyramidal or corticospinal tract dysfunction (effects occurring below the head (e.g., paraplegia, hemiparesis, etc.)

2. Cerebellar dysfunction (ataxia, both truncal and limb, etc.)

3. Brain stem dysfunction (pseudobulbar palsies, "scanning speech", nystagmus and cranial nerve functions, etc.)

4. Sensory dysfunction (vibration sense, decrease in touch, pain, or position sense, etc.)

5. Bowel and bladder dysfunction (hesitancy, urgency, retention, or incontinence, etc.)

6. Visual functions (the degree of impairment of vision in the worst eye)

7. Mental functions (mood alterations, mentation decrease, dementia, etc.)

8. Other functions not categorized previously (aphasia, seizures, etc. listed but not quantified).

These system evaluations are not intended to represent anatomical areas but rather functions of the central nervous system. They are graded in ascending order to indicate the severity of dysfunction. The scores on the FS are not additive, but the functional system rating of one individual may be compared to the identical system of another individual or one patient's scores in each system may be compared longitudinally for either improvement or loss of function.

Western Multi-dimensional Memory Battery (WMMB) (Way, 1979)

This instrument is a comprehensive memory test intended for clinical use, based on a clinical model of memory, utilizing an information-processing structural approach. It attempts to examine memory for modality (visual and auditory); content (verbal and non-verbal); temporal span (immediate, short term and long term); and type of retrieval (recall or recognition) as well as all possible combinations of these factors. It has been normed on a representative sample of 304 residents of London, Ontario with ages ranging from 20 - 70 years (see The Normative Group, discussed previously).

The content validity was established by Way (1979), by beginning with a battery of 54 tests designed to test 24 discrete memory functions and subsequently reducing this to the best 24 tests as a careful examination of the domain. There appears to be reasonable evidence for its face validity in that uninstructed

subjects commented "Oh, these are memory tests aren't they?". The psychological construct underlying the test is that memory is a construct independent of other constructs, such as intelligence,and is multifactorial. The convergent validity was tested using the Wechsler Memory Scale (Wechsler, 1945) as a whole ($r = .744$, $p < .001$). When the individual subtests on the WMMB were compared to those on the Wechsler, which purported to measure the same memory factors, the correlations of these selected subtests ranged from $r = .58$-$.72$. The split-half reliability coefficient varied between $r = .86$-$.91$ and thus it demonstrates adequate reliability.

Training of the Testers of the WMMB

It soon became evident that there would be a minimum of six hours of contact time with each subject. In order not to extend the time of data gathering unduly, it was decided to train an assistant to administer the tests. From the period of September 1983 to October 1985, during which the data was being obtained, a total of six individuals including the author were engaged in this process. However, at any one period only two people (the author and one other) were involved. All six testers had at least one graduate level course in testing. Their qualifications were as follows (a) Ph. D. - Psychology (1), (b) Master's - Psychology (2) and (c) B. Sc. - Psychology (2).

The testers familiarized themselves with the test kit, the time constraints, the test protocol and administered the test to at least one normal subject, according to the rules of standardized test administration. Any problems and/or questions on the test and procedures were discussed and a solution was found. The testers were reimbursed for their testing on an hourly basis from a grant from the Special Services and Research Committee of the University of Alberta Hospitals, obtained by the author.

Procedure

The individuals with MS who met the criteria described previously were contacted at their homes, by phone. The study was described with a brief outline of what would be expected of them and they were asked if they were willing to participate. If their permission was granted, an appointment was made for the initial interview to take place in their homes. For those subjects who were resident in auxiliary hospitals or nursing homes it was also necessary to obtain the signed consent of their physicians as well as their individual consent (see consent forms in Appendix C). During this first contact, the research was explained again and questions were invited and answered. If the consent form was signed, demographic information was obtained and the Peabody Picture Vocabulary Test-Revised was administered. The subjects were asked to set aside two, two and one-half hour periods on

different days for the administration of the Western Multi-dimensional Memory Battery (WMMB).

The test was divided into two parts in order to prevent undue fatigue of the subject. Once the memory testing was completed, Dr. K. G. Warren, a neurologist, rated their level of disability and the functional systems affected on the Expanded Disability-Status Scale (EDSS) (Kurtzke, 1955, 1965, 1983) and the Functional Systems (FS) (Kurtzke, 1983). He also categorized the course of the disease in each subject as being either (a) remitting, (b) remitting/progressive or (c) progressive.

All subjects were told that they could discuss their scores on the memory test or the research in general, with the author once the data had been analyzed. A record was kept of those who were interested in having this information.

Analysis of the Data

The primary goals of the analysis of the data were:

1. To compare the memory functioning of the MS group with the normative group.

2. To examine the relationship between memory functioning and demographic, disease and intelligence measures within the MS group.

An exposition of the models used and the decision processes related to their use will be fully described in the following chapter. A summary of the models and techniques used, follows.

In dealing with the memory variable, it was decided to use the profile analysis model of Cronback and Gleser (1953) and Skinner (1978), in order to decompose the scores on the 24 WMMB tests into a smaller number of components (elevation, scatter, shape) which might be more useful. Following the procedure, factor analysis was employed to ensure that this model was compatible with these data. Factor analysis was also used in the process of separating normal from abnormal memory scores as the data available on the normative sample contained only summary scores (i.e., means, standard deviations and an intercorrelation matrix) rather than individual scores. Therefore, the factor score coefficients resulting from the first factor were applied to the standard scores of the 24 subtests of the WMMB in the MS sample and resulted in scores expressed in standard score form which permitted the separation of normal from abnormal scores using a criterion of 2 SD below mean.

Cluster analysis enabled the further decomposition of the profile component, shape.

The second part of the analysis which dealt with the relationships between memory function and demographic, disease and intelligence measures in the MS group consisted of a form of regression analysis known as Path analysis.

CHAPTER IV

RESULTS

This study was designed to investigate the prevalance and nature of the memory deficit that is seen clinically in some MS patients. To this end the following research hypotheses were generated.

1. Subjects with the diagnosis of MS will obtain significantly lower scores on a memory test than will a normative group, similarly tested.

2. There will be a pattern of memory deficit common to those subjects who are judged to have significantly abnormal memory.

3. There will be a relationship between memory functioning and demographic factors, disease measures and intelligence in the MS group.

Subject Characteristics

The MS group consisted of 100 subjects (41 male and 59 female) chosen according to the criteria discussed in Chapter III. They had a mean age of 38.0 years (S. D. = 8.0), a mean education of 13.0 years (S. D. = 1.0), a mean IQ (verbal) of 97.7 (S. D. = 16.3), and a mean disease duration of 15 years (S. D. = 8.0). Their mean neurological disability as measured by the Kurtzke Scale was 4.2 (S. D. = 2.0) (see Appendix A, Tables A1, A2 and A3).

Assessment of Memory

Hypothesis 1

Subjects with the diagnosis of MS will obtain significantly lower scores on a memory test than will a normative group, similarly tested.

The instrument chosen to measure memory was the Western Multidimensional Memory Battery (WMMB) which consists of 24 subtests and therefore, of necessity the analysis was multivariate in nature. The overall memory score profiles that were generated were examined and the average scores of the normative group were compared to the MS group to see if there was any clinically meaningful result and none was apparent. A preliminary analysis was performed using a 3 x 2 x 2 x 2 repeated measures analysis of variance (see Appendix E) to look at the actual pattern of ups and "downs" across variables in the way the test constructor intended. The results were highly significant for most main effects, most 2-way interactions and most 3-way interactions and for the 4-way interaction. Essentially each score differed from every other score and no meaningful pattern was discernable. For this reason the model of Cronbach and Gleser (1953) with Skinner's (1978) adaptation was chosen as the means of analysing the profiles. This method divides profiles into separate components of elevation, scatter and shape. "Shape denotes the actual pattern of ups and downs across variables in the profile. Scatter

describes how dispersed scores are from the average, while elevation is the mean score of the individual overall attribute measures in the profile" (Skinner, 1978, p. 297) (see Figure 1).

Figure 2 is the average of profiles for all of the 100 MS subjects in which each test score was standardized against the scores of a large normal population. (See Appendix A, Table A4 for the means and standard deviations of the normative population on the WMMB (Evans, 1985) and Appendix A, Table A5 for the numerical plot of Figure 2.)

To examine the data under the Cronbach and Gleser model (1953) a factor analysis was first applied to both the normative and MS groups. Factor analysis (Nunnally, 1967) is frequently used to reduce a set of variables to a smaller number of variables which account for a substantial proportion of the variability of the full set of measures. Factor analysis was performed for three reasons: (a) to test the hypothesis that a smaller number of variables accounts for the variability of the complete set of 24 subtests; (b) to test the suggestion of Skinner (1978) that the first unrotated factor represents profile elevation; and (c) to provide a method for statistically separating individual subjects with impaired memory in the MS sample, from those with normal memory function when only means, standard deviations and an intercorrelation matrix (but not individual scores) were available for the normative group.

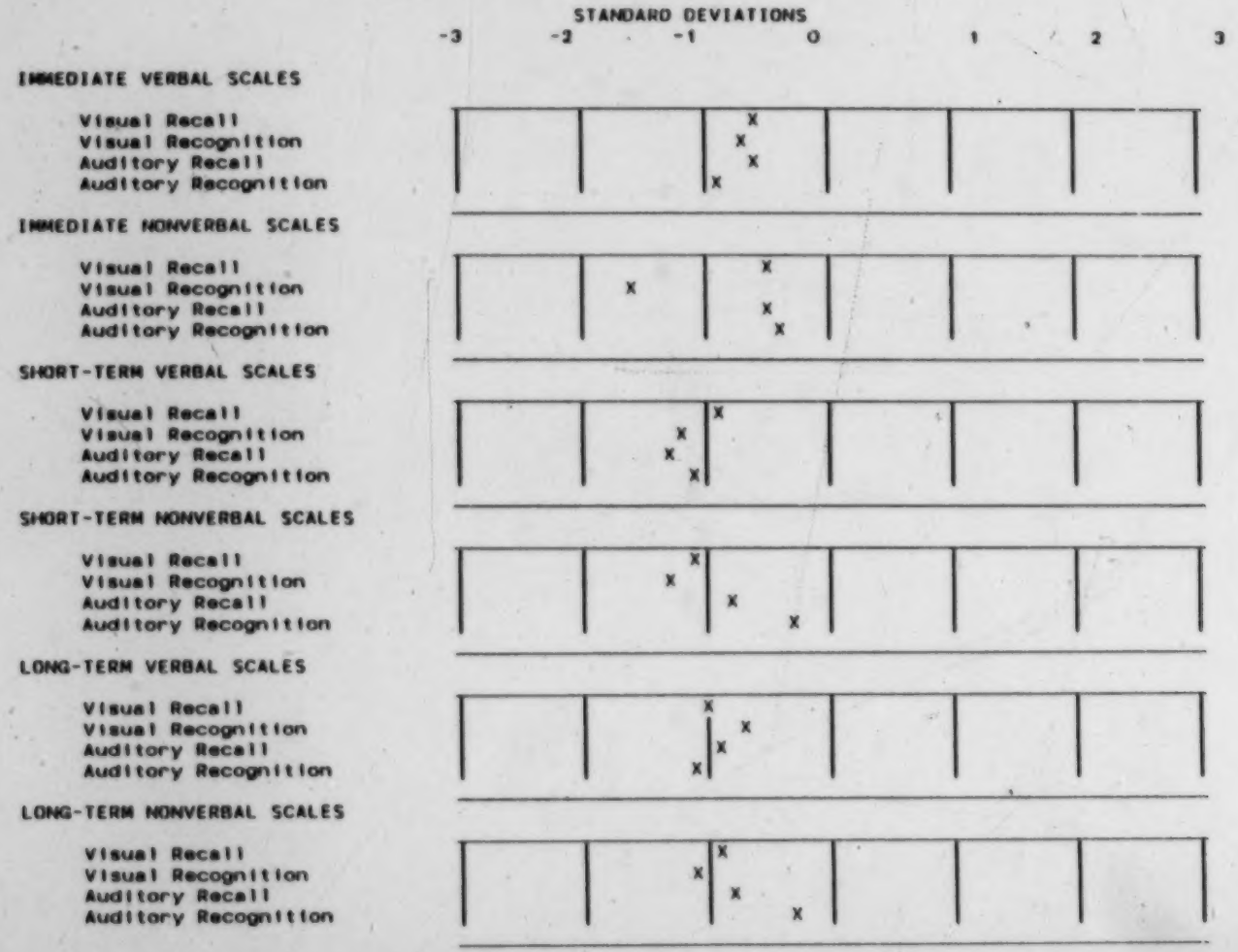
Figure 1. A graphic illustration of the properties of elevation, scatter and shape.

A. Two profiles differing only in elevation

B. Two profiles differing only in scatter

C. Two profiles differing only in shape

Figure 2. Average WMMB profiles on all 24 variables in standardized score form for 100 MS subjects standardized against normative population.



A principal components analysis was performed on the correlation matrix of the WMMB scores of the normal subjects (see Appendix A, Table A6). The first factor accounts for a substantial proportion of the variance (.42) and is substantially larger than the second largest factor (.06) (see Appendix A, Table A7). When the effects due to the first factor were removed, the mean (off diagonal) value was -0.0217 (S. D. = 0.0640) which strongly suggests that one factor is sufficient to account for the shared variation between the subtests of the normal population (see Appendix A, Table A8).

There is a wide difference of opinion regarding how many factors should be taken from any data. It was decided to adhere to the one factor solution for a number of reasons. As mentioned above, the first factor is substantially larger than all the others and when this first factor is removed, the residual correlation matrix contained values on the off-diagonal not very different from zero. As well, one factor is consistent with the model of profile analysis chosen, and a Scree Test (Cattell, 1966) showed that only one factor should be accepted. Reddon (1984) compared about 50 current statistical rules to determine how many factors should be attended to and found that attending to an Eigenvalue <1 rule generally results in too many factors in large data sets. In spite of this evidence for the use of the one

factor solution, a five factor solution was rotated but not found to be meaningful.

The factor score coefficients for the first factor were applied to the standard scores for the 24 subtests of the WMMB in the MS sample. These factor scores were correlated with (a) the factor scores for the first factor in an analysis of the scores for the MS sample alone ($r = .9992$) and (b) the sum of the standard scores of the 24 subtests (which is the definition given previously for elevation) ($r = .9975$). It can, therefore, be concluded that (a) the first factor score represents elevation and (b) the definition of elevation is consistent for the normal and the MS samples.

The application of standardized factor score coefficients derived from a normative population to standard scores (derived from the normal means and standard deviations) results in factor scores expressed in standard score terms. The use of standardized factor score coeffients on a normal population will result in scores with a mean of 0 and a standard deviation of 1. Application of this normalization procedure to scores of another population (the MS group) will result in normalized factor scores.

Although recalling that elevation is only one component of the decomposition of profiles into elevation, scatter and shape and therefore, not the only basis upon which a profile of memory functioning could be declared abnormal. In this case it accounts

for a very substantial proportion of the overall variation (41.91% in the normal population (54.33% in the MS population). It could, therefore, serve as a method for separating normal from abnormal subjects.

Assuming that factor scores for elevation are normally distributed, any standardized score less than -1.96 would be statistically likely to occur with a probability less than 0.05 if the subject's memory was normal. It was decided to use $\alpha = 0.05$ as the cutting point for determining normal from abnormal for the purposes of further analysis. Using this criterion 45 subjects were declared to have abnormal memory functioning and 55 were declared to have normal memory functioning. Figure 3 shows the average profiles on all 24 variables for the normal group while Figure 4 shows the average profiles on all 24 variables for the abnormal group.

The second component of the decomposition of memory scores, scatter, was calculated as follows: (a) all variables were standardized against normative values and the elevation was calculated using standard factor score coefficients derived from the normal population as described previously; (b) scores for the 24 subtests were subtracted from the scores that would have been predicted on the basis of the elevation component alone (using the prediction elevation standard score times subtest correlation with elevation); (c) these residualized scores were standardized

Figure 3. WMMB: Average profiles on all 24 variables in standardized score form for MS group declared normal in memory function ($p < .05$ (N = 55)).

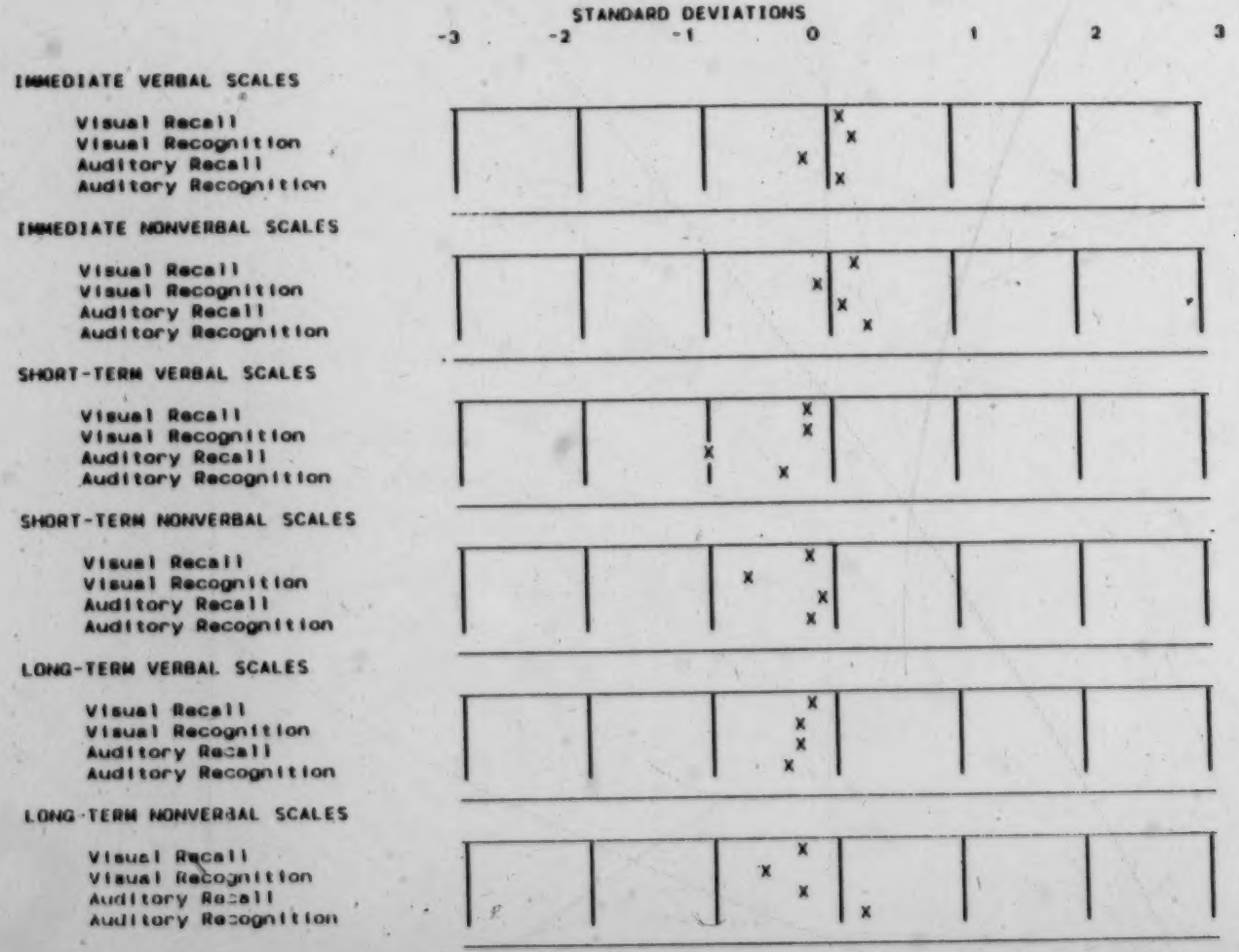
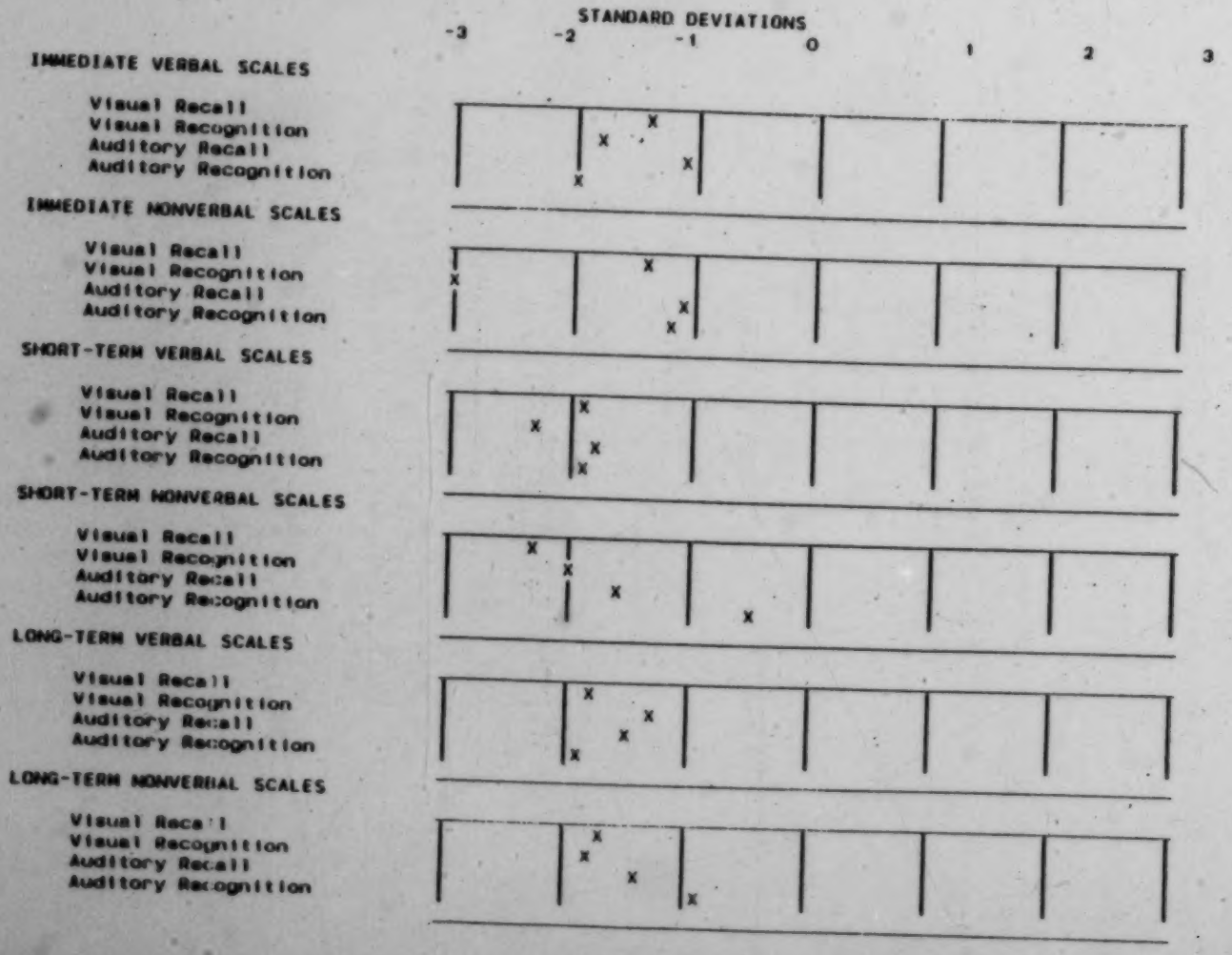


Figure 4. Average profile on all 24 variables in standardized score form for MS group declared abnormal in memory functioning ($p < .05$ ($N = 45$)).



against the standard deviations of similarly residualized scores in the normal population (as taken from the residual variances in the residual correlation matrix for the normal population, previously described); this procedure gives 24 standard scores for that portion of the variation not explained by the elevation component; and (d) since the correlation matrix of these residuals is assumed to be the identity matrix, the sum of squares follows a chi square distribution and can be used both (by definition) as a measure of scatter, in this case normed against the normal population and as an alternate means of testing for normality.

Using a similar criterion (χ^2 with 24 degrees of freedom at $p < 0.05 = 36.415$), 28 subjects can be shown to have abnormally high scatter. A cross tabulation shows that 16 of these also showed abnormally low elevation. Since by regression analysis scatter is shown to explain only 2.89% of the variation among profiles, its effect in predicting normality of memory functioning is minimal.

In summary, Hypothesis 1 that subjects with a diagnosis of MS will obtain significantly lower scores on a memory test than will a normative group similarly tested, was confirmed. Forty-five percent of the MS sample obtained scores more than two standard deviations below the mean.

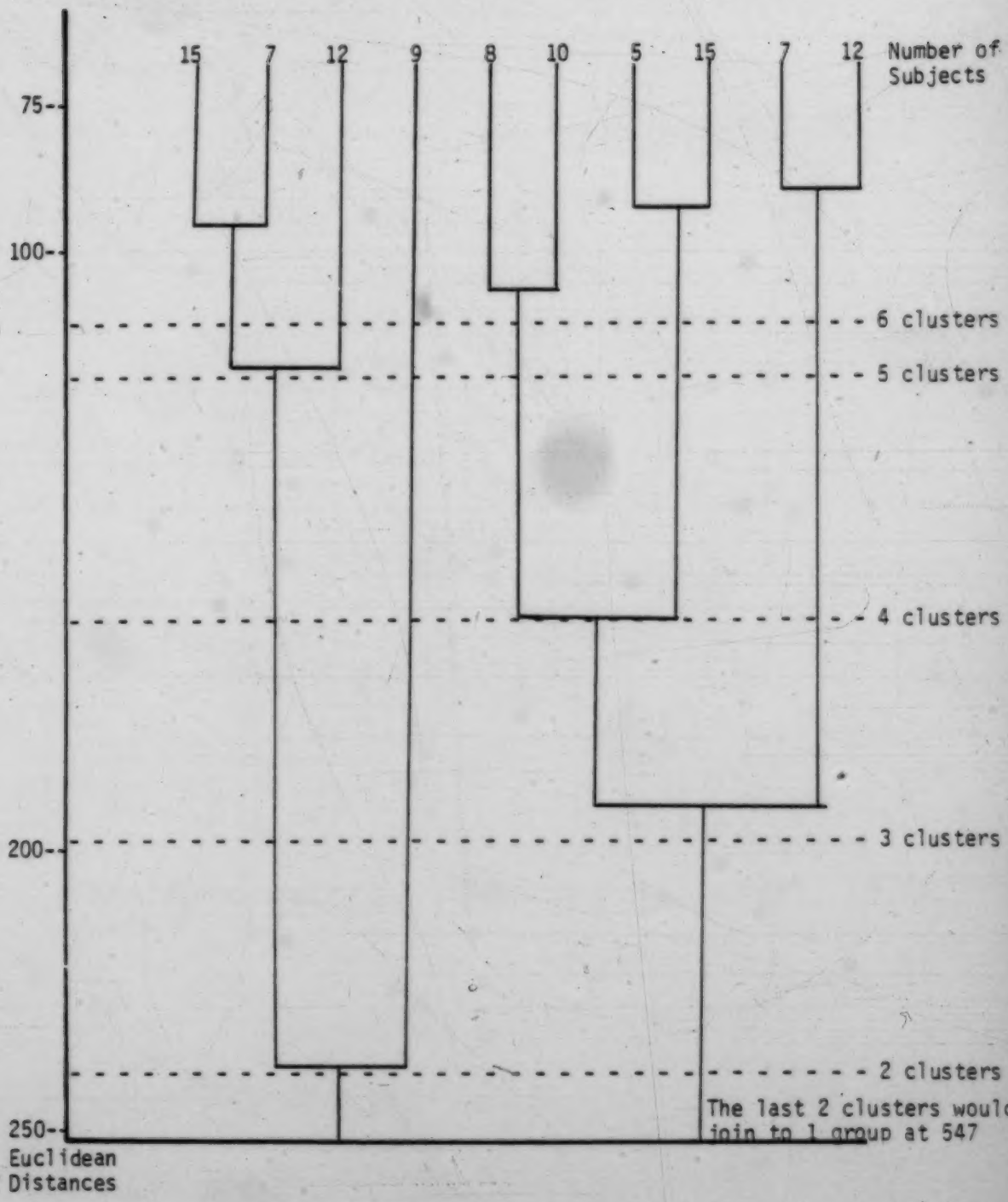
Hypothesis 2

Hypothesis 2 states that there will be a pattern of memory deficit common to those subjects who are judged to have

significantly abnormal memory. A visual inspection of the average profiles revealed that there was no good reason to say that any one group of tests (e.g., short-term verbal recall) were significantly lower than any other (see Appendix B, Figures B1 - 100). When an analysis was done to confirm this visual finding there were statistically significant differences at all levels of interaction but there was no way to interpret the differences which involved all the factors of modality (visual and auditory), content (verbal and non-verbal), temporal span (immediate, short-term and long-term), and type of retrieval (recall or recognition).

An alternative method of examining this hypothesis is based upon the model of Skinner (1978) and consists of the attempt to further decompose the shape component. The analysis employed the elevation residualized scores (discussed previously) with one further transformation. All 24 scores within a subject were standardized to have a mean of 0 and a standard deviation of 1. In this way no effects due to elevation or scatter were contained in the scores. These scores were clustered using hierarchical cluster analysis with a minimum variance criterion on Euclidean distances between each subject (cluster) (Ward, 1963). For interpretation purposes, standardized profiles of the cluster solution were generated (see Figure 5 and Appendix A, Figure A1).

Figure 5. Cluster dendrogram of the three cluster solution.



The three cluster solution was chosen on the basis of visual clarity (see Figure 6) (and therefore, possible clinical utility) of the group profiles, the distance measures of the dendrogram and were confirmed and quantified with the help of a stepwise multiple regression analysis (see Figures 7, 8 and 9).

This analysis consisted of beginning with the two clusters and entering into the regression equation separating these two clusters only those tests of the original 24 tests of the WMMB which separated these clusters at $\alpha < 0.001$. This procedure was successively iterated to the level of six clusters. The variables meeting the criterion at the level of six clusters were tests 2, 3, 6, 8, 11, 14, 18, and 24. These were then entered into a canonical analysis with the cluster classification for six clusters. The first two canonical variates accounted for 74.2% of the intergroup variance (see Appendix A, Table A9). Examination of the canonical structure weights showed that the tests 2, 6, 18, and 24 accounted for the primary separation between the six clusters (see Appendix A, Table A10).

Figure 6 shows the clusters (means and standard deviation) plotted against the two canonical variates. Note that the coalescence into three groups is what would be expected on the basis of the diagram. These two canonical variates were capable of classifying subjects into the three groups isolated by the cluster analysis with 100.0% efficiency and were then chosen as

Figure 6. Clusters (mean and standard deviations) plotted against the canonical variates.

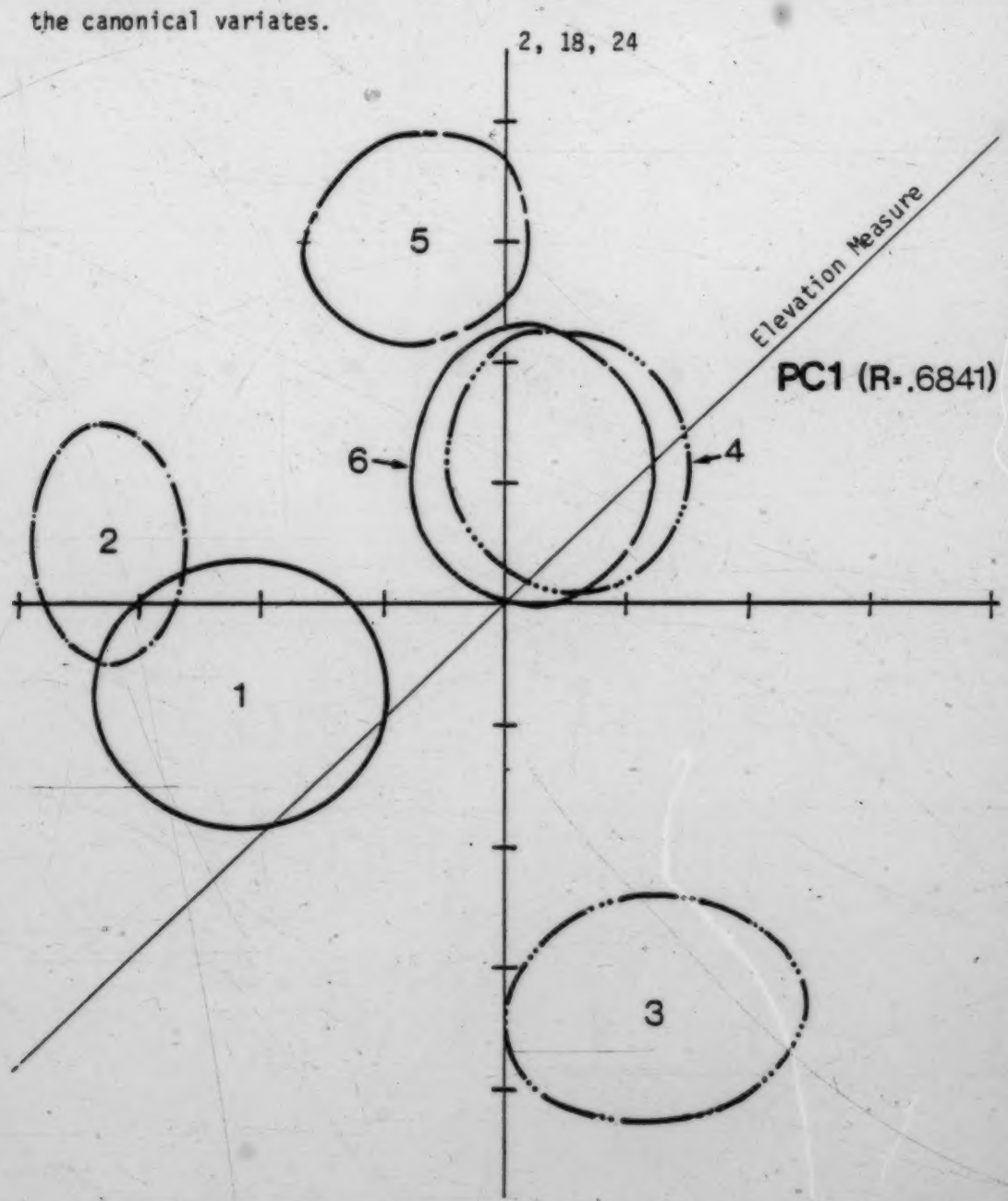


Figure 7. Cluster Three (of Three Cluster Solution).

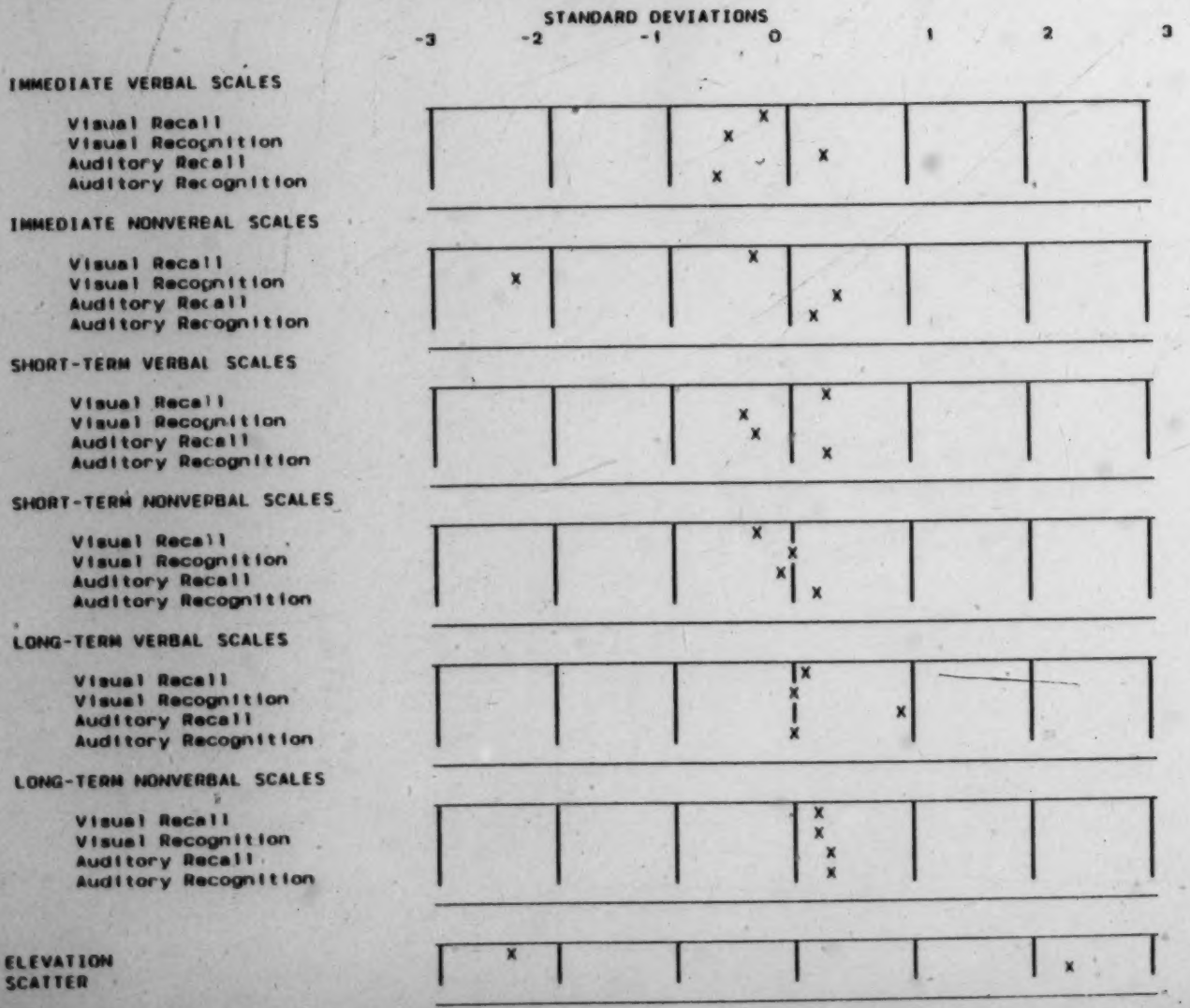


Figure 8. Cluster Two (of Three Cluster Solution).

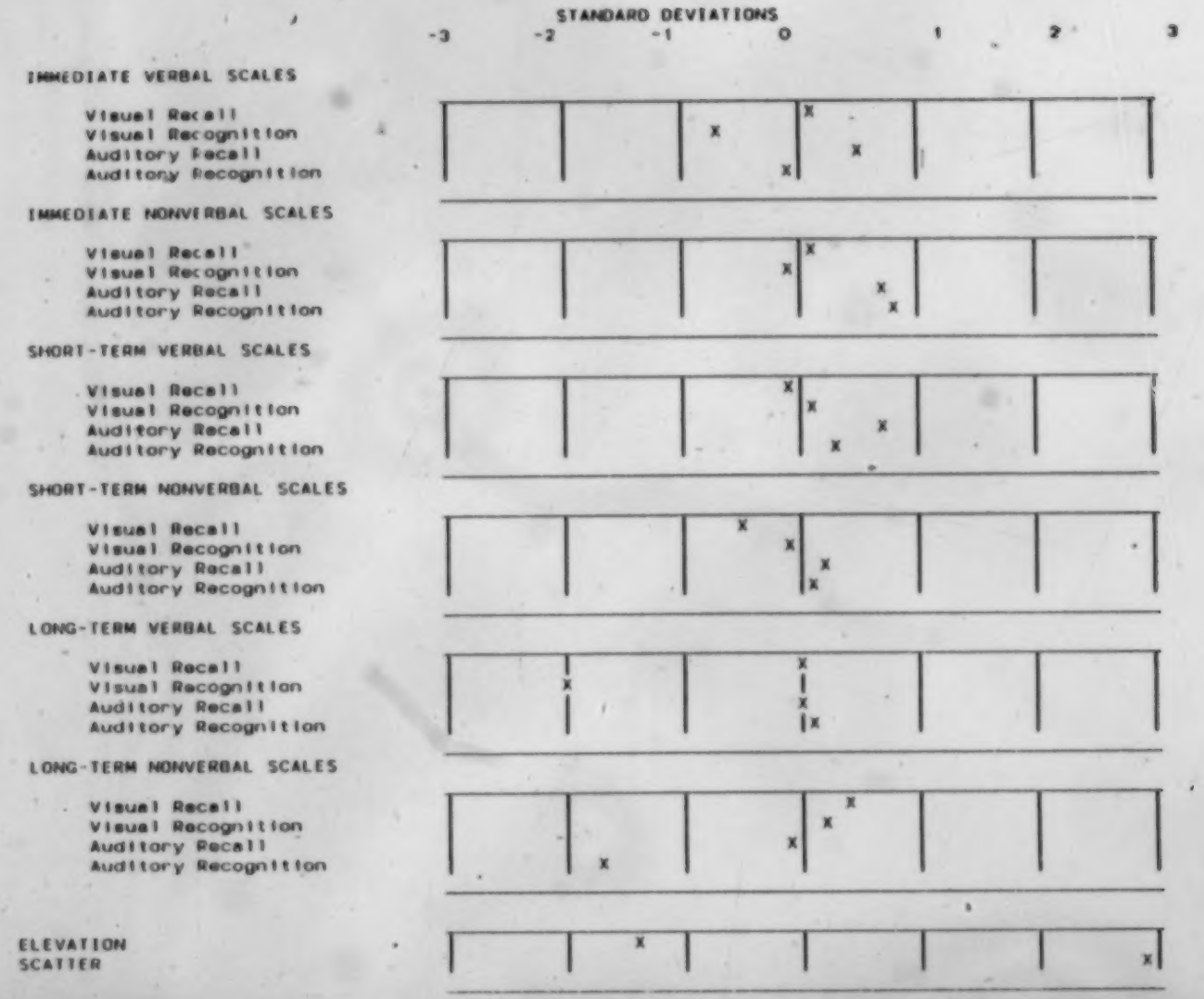
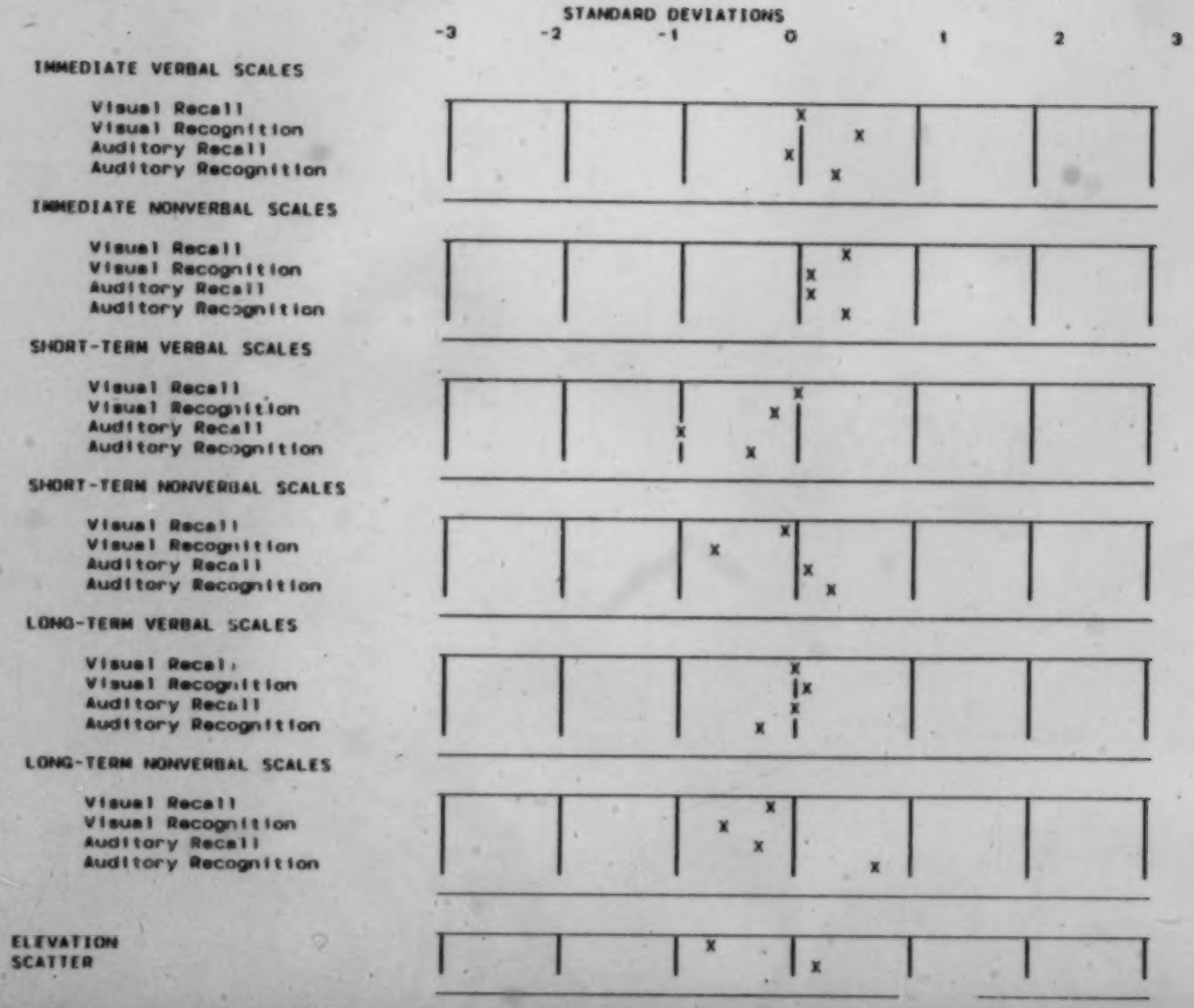


Figure 9. Cluster One (of Three Cluster Solution).



variables representative of the main dimensions of shape difference in the sample. Elevation contributes 54.33%, scatter 2.89% and shape 42.78% (the interaction of shape and scatter) to the full variation of the WMMB (see Appendix A, Tables A11 and A12).

The higher relationship between elevation and shape can be seen in Figure 6 (previously presented) in which the elevation measure is plotted in the same space as the shape dimensions (R = 0.68).

The relationship between elevation and scatter is suggestive of a ceiling effect in testing; normal subjects do not have the room to be highly variable in test performance since perfect scores are possible and are obtained, while with lower overall scores, more variability occurs.

The relationship between shape and scatter illustrates that the more scattered the profile, the more likely the subject will belong to a cluster indicative of abnormal memory.

The cross classification of the cluster membership with the normal-abnormal distinction determined by elevation scores suggests that members of cluster 1 are normal subjects with regard to memory scores and that clusters 2 and 3 more likely contain subjects with abnormal memory. This can also be seen on the cluster group profiles (see Figures 7, 8 and 9). A cross classification of cluster membership with the normal-abnormal

dimension according to elevation is given in Appendix A, Table A13.

Hypothesis 3

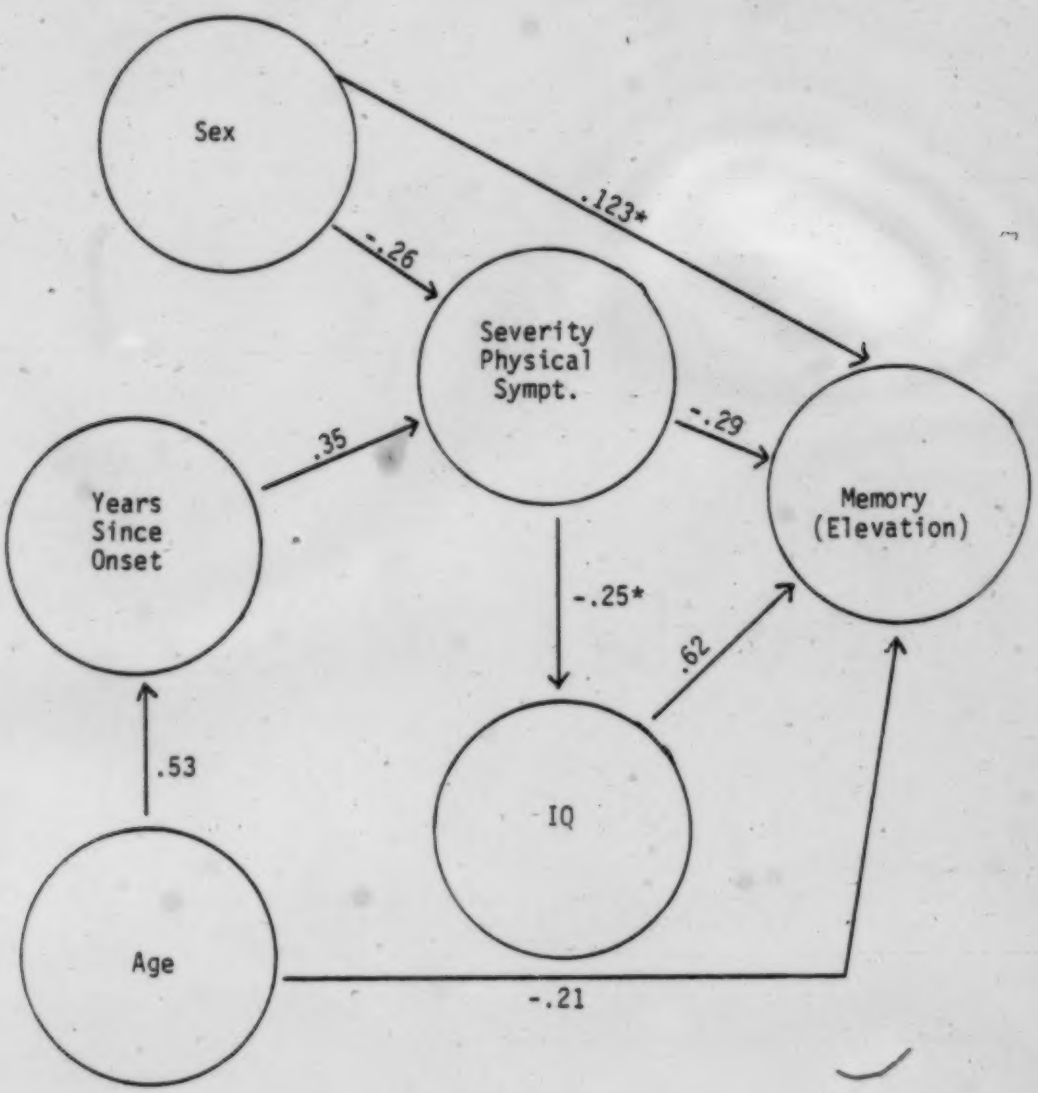
There will be a relationship between memory functioning and demographic factors, disease measures and intelligence in the MS sample.

As the single score of elevation accounts for the largest percentage of the information contained in the profile of scores, (see Appendix A, Table A11) for purposes of the analysis to follow, elevation was assumed to be the primary measure of memory. In the first stage of this analysis, a stepwise multiple regression between the elevation component of the memory battery and ancillary variables was performed. The resulting equation showed that sex, age, intelligence (as measured by PPVT), and severity of illness (as measured by the Kurtzke Expanded Disability Scale, Part I) were highly predictive of elevation of the memory battery ($R = .834$, $F = 43.1$, $P = <0.001$).

In the second stage a variety of structural models were examined. Using the multiple regression related methods of Cohen and Cohen (1983) the path analysis of Figure 10 resulted (see Appendix A, Tables A14 - A17).

The path coefficients in Figure 10 are partial beta weights calculated in successive multiple regression analysis in which for the prediction of any variable in the network, all variables with

Figure 10. Path analysis of memory with demographic, disease and IQ variables.



*p <.05

all others p <.01

a direct influence are included and all variables exerting an influence on these variables are also included. Any path which is not included in the diagram is not significant. The residual correlation matrix of the six variables will tend toward zero if the model explains the data relationships. The residual matrix is presented in Appendix A, Table A18.

These results shows that (a) memory is strongly related to intelligence ($r = .62$), (b) the severity of multiple sclerosis is negatively related to intelligence ($r = -.25$) and (c) the severity of multiple sclerosis has an independent negative relationship with memory ($r = -.29$).

When scatter and the two shape components are entered into the analysis, none of the ancillary variables significantly increased the predictability of these components beyond that supplied by elevation alone; with the exception that sex correlates with the first shape component ($r = .253$, $p < 0.05$) reflecting a mild tendency for females to be underrepresented (in the cluster with nine subjects and low scores in tests 18 and 24). This suggests that neither scatter nor the two shape components find external validation in this data.

Hypothesis 3, that there is a relationship between memory and the demographic, disease and intelligence variables is, therefore, confirmed.

Additional Analyses

Analysis of the Kurtzke Scales (Functional Scales, Part II)

A principal component factor analysis was performed on the correlation matrix of the seven functional scales for the 100 MS subjects. Table 1 shows the eigenvalues (and hence, proportion of variance) attributable to the unrotated principal components as well as the variable loadings for these components. The first factor accounts for a very substantial portion of the total variation among the scales. Despite the fact that by most criteria only a single factor should be considered, two factors were rotated for exploratory purposes. The resulting factor loadings for the seven scales on the two factors are shown in Table 2.

It can be seen that the first factor had substantial relationships with all Kurtzke Scales except the Mental Scale, while the second factor has a major loading for the Mental Scale and smaller loadings for the Visual and Brainstem Scales. Factor 1 has a correlation of .9287 with the overall Kurtzke Scale while Factor 2 has a correlation of .1920 with the scale (see Appendix A, Table A19). This strongly suggests that the first factor is representative of a general disability scale. It also suggests that the major variation among the seven functional scales is related to a general elevation (or severity of dysfunction) which is represented by the Kurtzke Scale score.

Table 1

Variance Attributable to the Unrotated Principle Components of the Kurtzke Scales (Functional Scales, Part II) (N = 100)

Variable	Commonality	Scaled Factor Loadings				
		1	2	3	4	5
1. Pyramidal	0.90	0.91	0.23	0.14	0.05	0.03
2. Cerebellar	0.98	0.86	0.21	0.12	-0.14	0.40
3. Brainstem	0.95	0.87	-0.15	-0.01	-0.35	-0.02
4. Sensory	0.88	0.91	0.08	0.02	-0.07	-0.21
5. Bowel/Bladder	0.96	0.85	0.27	0.09	0.38	-0.12
6. Visual	0.99	0.67	-0.30	-0.66	0.10	-0.09
7. Mental	0.99	0.46	-0.81	0.35	0.12	-0.05
Eigenvalue		4.53	0.93	0.61	0.32	0.27
Percent Variance		64.70	78.20	86.90	91.59	95.40

Table 2

Factor Loadings for Seven Kurtzke Functional Scales (Part II) on Two Factors

Variable	Commonality	Factors 1	Factors 2
1. Pyramidal	.88	0.92	0.19
2. Cerebellar	.79	0.86	0.18
3. Brainstem	.78	0.72	0.51
4. Sensory	.83	0.85	0.31
5. Bowel/Bladder	.80	0.88	0.12
6. Visual	.54	0.47	0.56
7. Mental	.86	0.06	0.92
Sum of Squares		3.86	1.61
Percent Variance		55.20	78.20

For exploratory purposes the second factor was entered into the regression equation defining the model presented in the previous section. As seen in Tables 3 and 4, the second factor has a statistically significant partial correlation with the elevation component of the memory battery even after all other variables in the model (including the overall disability score of the Kurtzke Scale) are controlled. This suggests that the second factor which appears to be primarily related to the neurologist's rating of the patient's degree of mental deterioration is sensitive to actual memory loss as measured by the WMMB.

Clinical Use of Subtests of the WMMB

An exploratory analysis was undertaken to determine whether a smaller number of subtests than the full 24 tests could be employed to measure the principle variables underlying the WMMB. An examination of the factors of shape previously discussed showed that tests 2, 6, 18 and 24 were principle variables loading on these factors. Tables A20 - A23 (see Appendix A) show the results of regression analysis in which these variables were used to predict elevation, shape and scatter scores. Except for scatter, all can be well predicted. For comparative purposes a series of stepwise regressions were performed to predict elevation using the original 24 variables. Each analysis chose the best four variables not previously used in a set. The first three sets were:

Table 3

Extension Analysis of Path Analytic Model to Include Factor II of Kurtzke Disability Scale (Part I)

	D. F.	Sum Squares	Mean	F	Significance
Regression	6	126.12	21.02	41.11	.000
First	1	5.20	5.19	10.16	.002
Error	93	47.44	.51		
Total	99	173.67			

Multiple R = .85

Table 4

Extension Analysis of Path Analytic Model to Include Factor II of Kurtzke Disability Scale (Part II)

	Coefficient	Std. Error	t	Significance
Constant	-4.56	0.64	-7.16	.000
1. Second Kurtzke Factor	-0.24	0.76	-3.19	.002
2. Sex	0.29	0.15	1.88	.0626
3. Age	-0.03	0.01	-3.12	.002
4. Years Since Onset	0.00	0.01	0.05	.956
5. Disability Scale Total	-0.01	0.00	-4.39	.000
6. IQ	0.04	0.00	9.88	.000

4, 10, 13, 23 R = .97355

5, 8, 17, 20 R = .97109

6, 7, 9, 12 R = .96293.

This again confirms the dominance of the elevation component in the WMMB.

Examination of the Relapsing, Relapsing/Progressive and Progressive Diagnostic Distinction with Relation to Memory in Multiple Sclerosis Patients

Profiles on the WMMB and descriptive measures on all variables are presented for the relapsing, relapsing/progressive and progressive forms of MS (see Table 5). Figure 11 represents the memory profile of MS subjects with relapsing disease course. Figure 12 represents the memory profile for MS subjects with a relapsing/progressive disease course. Figure 13 represents the memory profile for MS subjects with a progressive disease course.

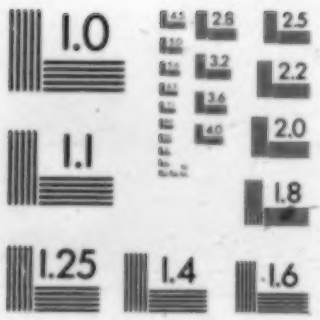
A further examination using two way cross tabulation examining the disease course categories is found in Appendix A (Table A24 (memory scores), Table A25 (gender), Table A26 (marital status), Table A27 (occupational category), and Table A28 (employment status)).

A stepwise discriminant analysis of the remitting, remitting progressive, progressive distinction shows that only the overall Kurtzke Scale Score and age contribute to the separation of groups. Note also that the Kurtzke Scale Score is the very

Table 5

The Descriptive Variables for the MS Subjects with the Three Disease Courses

	Relapsing		Relapsing Progressive		Progressive	
	X	S. D.	X	S. D.	X	S. D.
1. Age	36.2	7.9	35.6	6.9	43.5	7.5
2. Education	13.6	2.9	12.6	2.3	12.6	2.2
3. IQ	101.4	15.8	95.9	16.8	94.7	16.0
4. Years since Onset	12.4	7.3	13.8	7.1	19.2	8.0
5. Years since Diagnosis	8.3	5.6	9.1	6.0	13.6	6.3
6. Kurtzke Part I	1.7	1.8	5.1	2.4	6.3	2.3
7. Kurtzke Functional Systems						
a. Pyramidal	1.1	1.4	3.3	1.5	4.2	1.5
b. Cerebellar	0.5	1.1	2.3	1.2	2.2	1.2
c. Brainstem	0.5	0.6	1.5	1.0	1.7	1.2
d. Sensory	0.5	0.9	1.7	1.0	2.3	1.1
e. Bowel/Bladder	0.7	1.2	2.1	1.4	2.7	1.5
f. Visual	0.8	1.4	1.4	1.1	2.0	1.6
g. Mental	0.2	0.5	0.4	0.6	0.6	0.9


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

MicroD

Figure 11. Average WMIB profiles on all 24 variables in standardized score form for MS subjects with relapsing disease course.

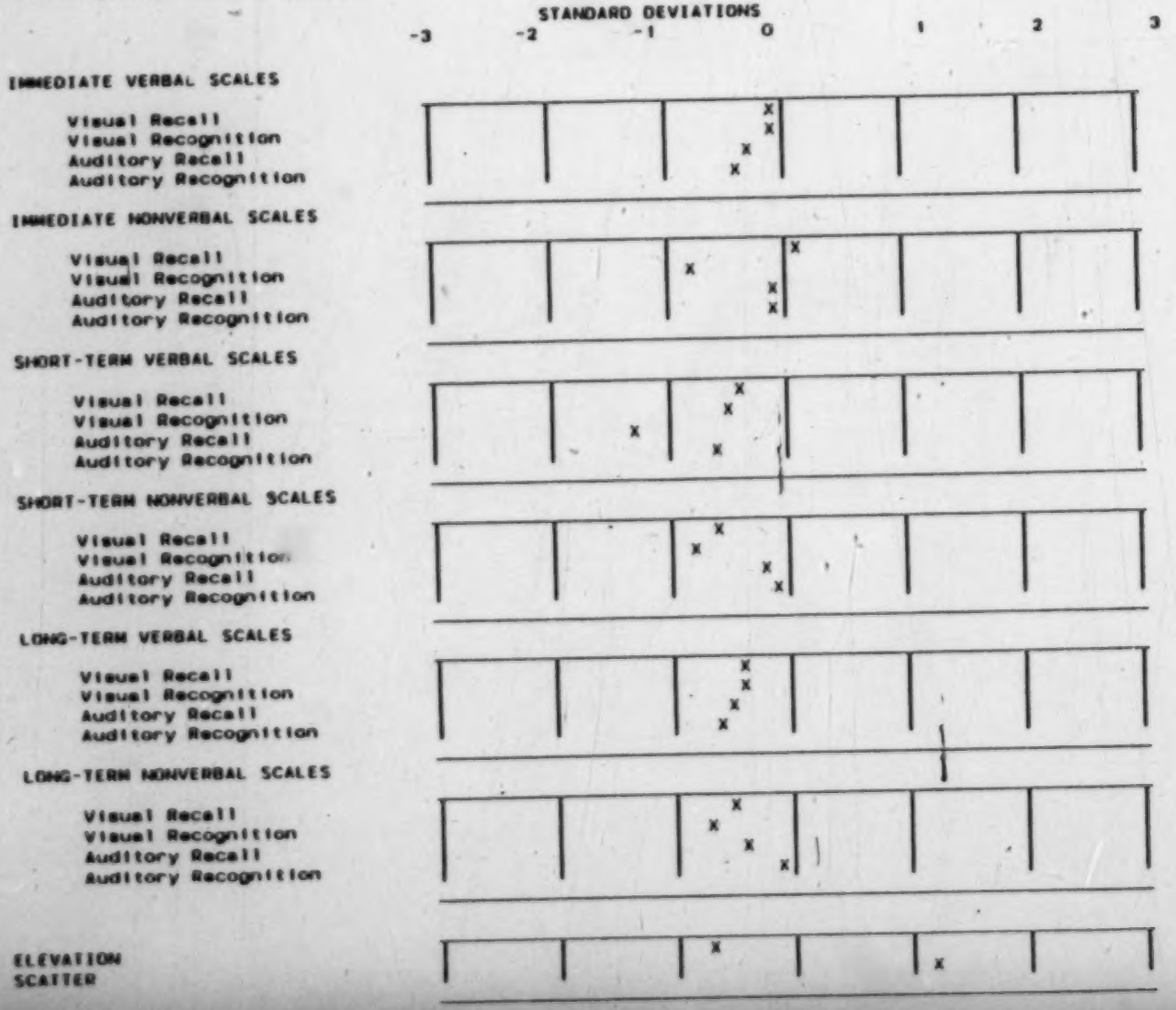


Figure 12. Average WMMB profiles on all 24 variables in standardized score form for MS subjects with relapsing/progressive disease course.

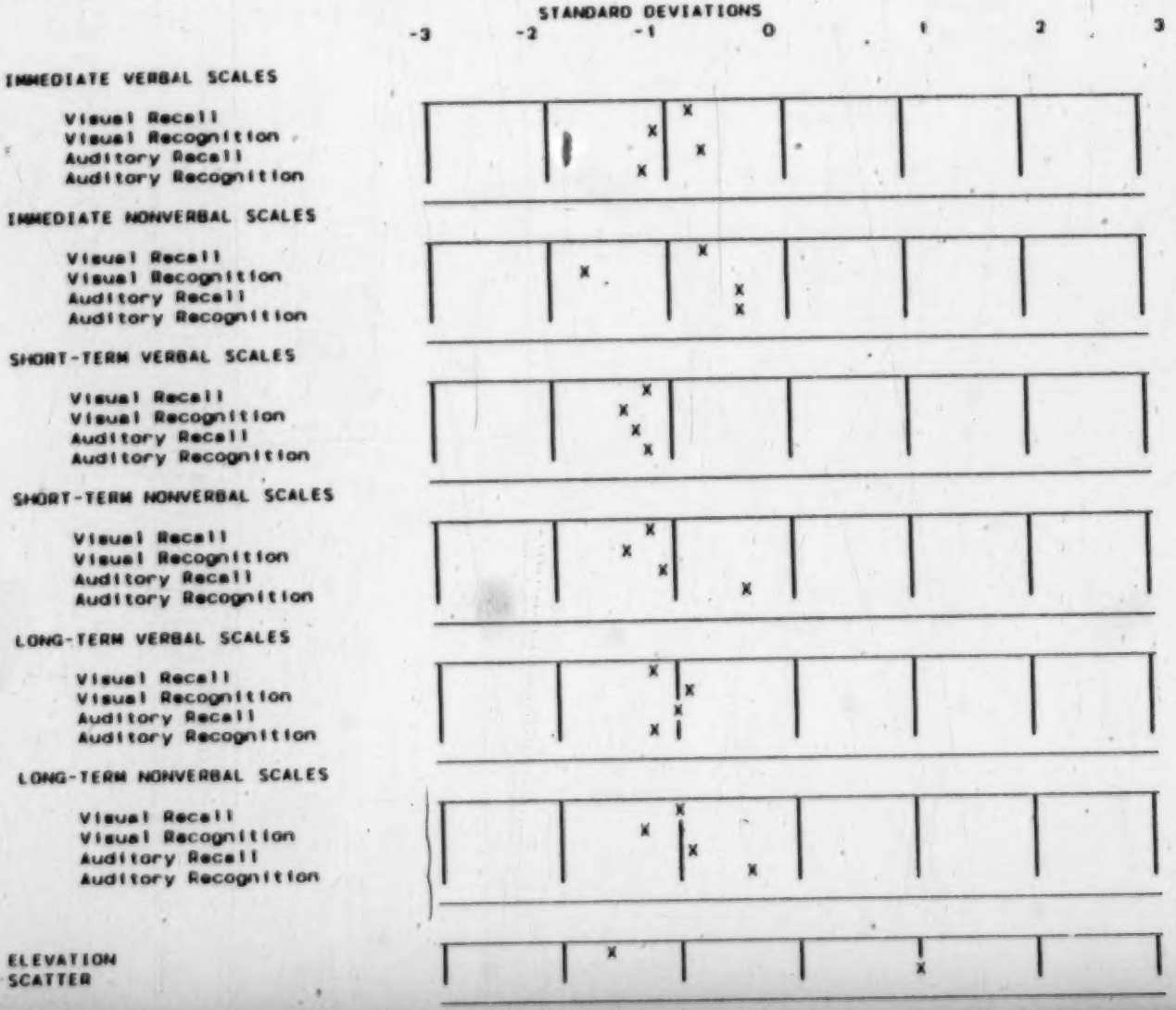
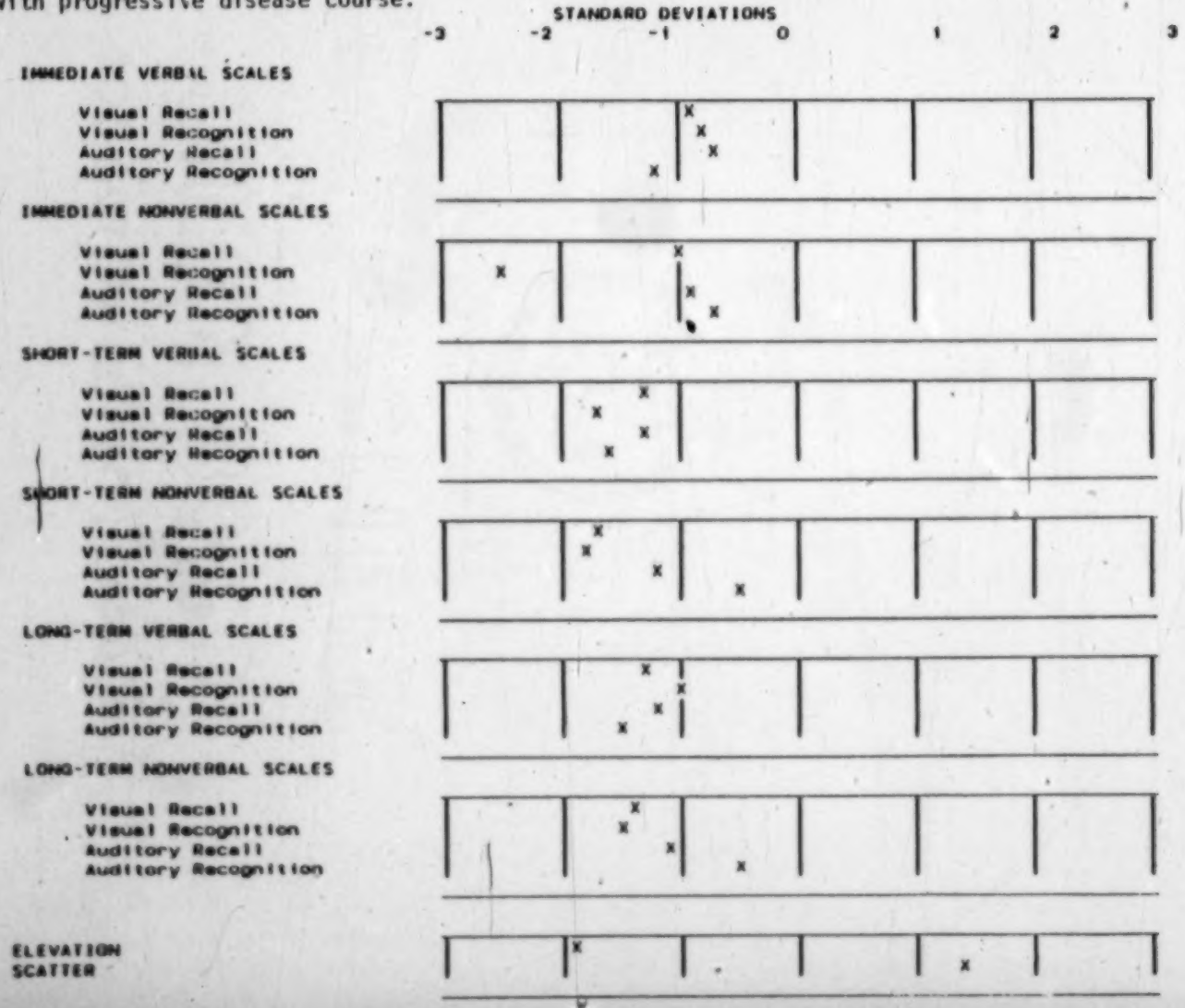


Figure 13. Average WMMB profiles on all 24 variables in standardized score form for MS subjects with progressive disease course.



largest separator (see Appendix A, Table A29). It might be concluded that this distinction yields little information beyond that found in previous analyses.

A Demographic Comparison of Normal Memory Versus Poor Memory Subjects

Presented in Table 6 are the descriptive and disease variables for the two groups of MS subjects separated on the basis of their elevation scores on the WMMB.

Two way cross tabulations of the normal/abnormal memory dimensions are presented in Table 7 (sex), Table 8 (marital status) and Table 9 (employment status).

Table 6

Descriptive Measures and Disease Variables of the 100 MS Subjects Divided into Those with Normal Memory (N = 55) and Poor Memory (N = 45)

	Normal Memory			Poor Memory		
	N	X	S. D.	N	X	S. D.
1. Age	55	36.2	8.0	45	40.8	7.8
2. Education Level	55	13.8	2.6	45	12.0	2.1
3. IQ	55	106.4	13.8	45	87.0	12.3
4. Years Onset	55	13.5	7.8	45	16.7	8.0
5. Years Diagnosis	55	8.6	5.9	45	12.1	6.4
6. Kurtzke D. S.	55	2.9	2.8	45	5.6	2.4
7. Pyramidal	55	1.9	1.9	45	3.8	1.6
8. Cerebellar	55	1.0	1.3	45	2.4	1.1
9. Brainstem	55	0.8	1.0	45	1.6	1.1
10. Sensory	55	1.0	1.1	45	2.0	1.2
11. Bowel/Bladder	55	1.1	1.4	45	2.5	1.5
12. Visual	55	0.9	1.2	45	2.0	1.5
13. Mental	55	0.2	0.4	45	0.7	0.8

Table 7

Two Way Cross Tabulation of Normal/Abnormal Memory Dimensions and Sex Category

	N	Abnormal Memory	Normal Memory
Male	41	25	16
Female	59	20	39
Totals	100	45	55

chi square 7.16 $p = .01$

Table 8

Two Way Cross Tabulation of Normal/Abnormal Memory Dimensions and Marital Status Categories

	N	Abnormal Memory	Normal Memory
Single	23	8	15
Married	55	21	34
Separated	5	3	2
Divorced	16	13	3
Widowed	1	0	1
Totals	100	45	55

chi square 11.77 p = .05

Table 9

Two Way Cross Tabulation of Normal/Abnormal Memory Dimensions and Employment Status

	N	Abnormal Memory	Normal Memory
Working	51	10	21
Not Working	17	5	12
Not Working due to MS	52	30	22
Totals	100	45	55

chi square 7.0872 p = .05

CHAPTER V

DISCUSSION

The goals of this study were threefold; firstly, to examine the memory functioning of a sample of MS patients and by comparison with a normative group to determine how many of the sample could be judged to have abnormal memory function; secondly, to determine whether among those patients exhibiting abnormal memory there was any pattern to this memory deficit (i.e., did most subjects perform more poorly in a patterned way with the loss being primarily in the area of verbal versus non-verbal, auditory versus visual, long-term versus short-term versus immediate memory or in recognition versus recall or any combination of these factors); and thirdly, to look for relationships between memory functioning, demographic factors (age, sex, etc.), disease measures (years since diagnosis, disability ratings, etc.) and intelligence (as measured by receptive vocabulary) in the MS group.

Hypothesis 1

Subjects with a diagnosis of MS will obtain significantly lower scores on a memory test than will a normative group, similarly tested. This hypothesis was confirmed in that using a conservative criterion on a measure of profile elevation, 45% of the MS group could be judged to have abnormally poor memory function. This deficit in the group of 45 MS subjects can be

described as a general memory deficit in that the average of scores over all tests of the memory battery were significantly lower than those of the normative group.

Hypothesis 2

There will be a pattern of memory deficit common to those subjects declared to have abnormal memory (i.e., these subjects will tend to find most difficulty in one or two facets of memory). One example of such a pattern would be a group who had all obtained low scores in short-term visual, non-verbal memory or perhaps some other combination of temporal, modality, content, and type of retrieval. This hypothesis was disconfirmed. A visual inspection of the 100 MS subjects' memory profiles (see Appendix B, Figures 1-100) shows that among those subjects in the abnormal group (N = 45) the scores are scattered and other than a general low elevation of scores, no pattern clearly emerges.

The failure to find a pattern based on the conceptual divisions inherent in the memory test may be due to at least two possibilities. One possibility is that the instrument used was not sufficiently sensitive to the different aspects of memory. This explanation gains support from the factor analysis which was performed on the scores of the normative group on the WMMB. Only one major factor emerged. This factor is identical with the major factor which was produced from the scores of the MS sample. In the MS group this first factor accounts for a very substantial

portion of the overall variance (54.33%). The other possibility is that no such pattern of selective loss exists and that the deficit due to the disease process in MS is a general lowering of all memory ability regardless of temporal span, modality, content, or method of retrieval. This situation could be due either to the undifferentiated way in which the disease affects cognitive processes in general including memory, or to the scattered and somewhat random occurrence of the MS placques which would affect each individual differentially. Because the test was unable to discriminate between the various memory factors, it is not possible to state unequivocally whether or not a pattern exists. It seems likely, however, that given the variable nature of placque location that there is not a pattern of memory deficit common to MS patients.

It was possible by cluster analysis to divide the MS sample into at least three clusters or patterns using the elevation component. Cluster I consists mainly of subjects with normal memory whereas Clusters II and III contain more subjects with abnormal memories and whose scores appear to be more scattered and also of lower elevation. The clinical utility of these divisions is not immediately apparent.

Hypothesis 3

There is a relationship between memory functioning, demographic factors, disease measures, and intelligence. This

hypothesis was confirmed in that there is a relationship among all these factors. A path model was constructed which demonstrated these relationships. Some of the individual relationships present in the model are what one would logically expect, as in the relationship between age and "years since onset of the disease". Also, as MS is a progressive disease, the influence of "years since onset" on the severity of the physical symptoms of the disease is what would be intuitively anticipated.

The complex relationships between IQ and memory has been an area of frequent study. Wingfield and Byrnes (1981) point out that the ability to remember is not the same as the ability to understand and that although not all facets of memory performance are related to intelligence (e.g., young children, elderly people and retarded people appear to have approximately the same short-term memory capacity as other people do, but lack the strategies to efficiently transfer the information to long-term storage) (Ellis, 1970; Flavell, Beach & Chinsky, 1966). Notwithstanding these complexities it is generally accepted that the higher one's IQ, the more likely one will have a good memory (Belmont, 1978; Dube, 1982; Eysenk, 1977; Hunt, Lunneborg & Lewis, 1975). The finding of the strong positive relationship between IQ and elevation memory scores is therefore an expected result.

A finding of interest is the negative relationship between the severity of the disability due to MS, and the intelligence

level suggesting that the physical progression of the disease is accompanied by a loss of intellectual function, across the entire sample. There is an independent negative relationship between the severity of the disease as defined by the Kurtzke scale ratings and the elevation of the memory scores, or in other words, the more severe the individual's disability, the more likelihood that their memory will be functioning less efficiently. This relationship exists independently from the individual's IQ. There is also a slight tendency for males to have poorer memory but for females to be more seriously affected physically.

Additional Analyses

Kurtzke Scales Part II (Functional Systems Scale)

Using factor analytic techniques, two factors account for a substantial proportion of the variation among the seven functional scales of the Functional Systems Scales (Part II). The first factor loads on all the scales except the mental scale and probably represents a general disability factor. The second factor which is much smaller, loads primarily on the mental scale but also to a lesser extent on the visual and brainstem scales. The second or mental disability factor is sensitive to general memory loss as measured by the WMMB.

Clinical Use of the WMMB

The WMMB is a lengthy battery of tests which taxes the energy of the MS subject. An analysis was undertaken to determine which

particular and fewer tests might be administered in order to predict the elevation scores. It was determined that almost any set of four tests would be predictive of the general memory ability of the subject. The best combinations of tests follows:

Set 1: Test Numbers 4, 10, 13, 23

Set 2: Test Numbers 5, 8, 17, 20

Set 3: Test Numbers 6, 7, 9, 12.

It was found that if any of these sets of four tests were used (in place of the 24 individual tests), one would be able to predict the general memory ability of the subject.

An Examination of the Three Diagnostic Groupings of Multiple Sclerosis Subjects with Regard to Memory

In Chapter I, the three diagnostic disease course groupings were discussed with a definition given for the relapsing, relapsing progressive and progressive disease courses. When the sample was categorized into these three groupings by a neurologist it was discovered that the Kurtzke Disability Scale (Part I) was highly related to this distinction. Only age information would add to the accuracy of classification into the three groups that could be achieved by the Kurtzke Disability Scale (Part I) alone. All additional trends such as the subjects in the relapsing group tending to be younger, to have a higher IQ, to have passed fewer years since onset and diagnosis, and to have a lower disability level than those in the progressive grouping are directly

predictable from the Kurtzke-Disability Scale (Part I) and the path model previously presented.

Demographic Comparison of Normal Versus Poor Memory Subjects

When the MS subjects were divided into two groups (good versus poor memory) on the basis of their elevation scores on the WMMB, those declared to have poor memory were older, had lower IQs, had had onset and diagnosis for a longer period and had a higher level of disability, exactly as predicted by the path model delineated in Chapter IV.

Summary of Findings

This study confirms the clinical experience of many people who work with individuals with multiple sclerosis--that a significant number of these individuals experience problems with their memory and that this loss of memory function is related to the severity of the physical disability, the length of time the individual has had the disease and appears to be concomitant with a lowered general intellectual ability level.

Limitations of the Study

The sample of patients chosen for this study is probably sufficiently unbiased and large enough to be able to demonstrate statistical differences in symptom expression in general and memory problems in particular, even taking into account the extremely variable nature of the disease course and expression, which is characteristic of MS. One group, however, could not be

examined at all and that includes the number of patients who were so disabled by severe vision loss or emotional problems or psychiatric disturbances, including dementia, that they were unable to perform the required testing. Although this is not a large group, clinical experience suggests that severe memory deficits are frequently present but are untestable.

It must also be acknowledged that the symptom expression of MS may vary for different races. While both black and white North Americans and Europeans may experience in general the same percentages of various symptoms, Orientals experience predominantly optic symptoms (K. G. Warren, personal communication, April 15, 1986) and therefore, the findings of this study will not generalize to this group.

Another limitation of this study relates to the decision to collect and examine the data using a quantitative paradigm which has certain inherent assumptions about scientific inquiry and the type of questions to be asked. The nomothetic method used here, attempted to establish certain "facts" about memory in MS in general, using a large number of subjects, objective measurement and statistical analysis. Although this was the method of choice, it must be admitted that in quantitative analysis the unique flavor of the person is lost. The specific nature of the memory loss in each individual, its emotional impact and its effect on their life situation is sacrificed in an attempt to establish some

basic principles. Another study might choose to examine the memory deficit of a few individuals in great depth, looking not just at the existence of deficits but looking also at the singular nature of those deficits and the correspondence between the test results and the real-life situations. The impact of the same degree of deficit can be varied depending on the life situation of the individual (e.g., memory loss in a member of the work force will impact differently than on a person who is primarily at home). One could also examine ways in which they attempt to compensate for the loss and of course this opens up the whole area of the remediation of memory.

Theoretical Implications

In the review of the literature on memory, presented in Chapter II, the theoretical basis of this research was the multi-store structural model of memory of Atkinson and Shiffrin (1968) with its temporal stores, including content, mode of reception and method of retrieval factors. Although the test used does not confirm these distinctions, neither does it provide evidence that they do not exist but rather that it was not capable of making the necessary discriminations.

It is also possible that the memory loss in MS is more closely related to that seen in the mixed dementia associated with neurodegenerative disorders described by Joynt & Shoulson (1985) which are characterized by a gradual and general loss of

intellectual function including mnemonic ability. On post-mortem examination, MS placques tend to be found bilaterally (Brooks, Leenders, Head & Marshall, 1984; Rao et al., 1984) which would increase the difficulty in trying to make the verbal - nonverbal loss distinction. The location of placques may differ from one individual to another so that there may be little similarity in the resultant damage to the brain. This is the opposite picture from, for example, the lesions in Korsakoff's syndrome where the memory loss is due to the atrophy of medial diencephalic structures only (Victor, Adams & Collins, 1971) or damage to the hippocampus found in post-encephalitis or anoxia (Milner, 1970). In the latter two diseases, the location of the disease process is specific, as are the resultant types of memory loss, whereas in the MS patient the lesions may be found throughout the cerebral structures and the memory loss of one individual with MS may have little in common with that of another individual with MS. This view of the extremely individualistic nature of the expression of brain damage is also supported by the work of Luria (1973) who saw the organization of the brain as an integrated functional system whose entire operation might be disrupted by damage to even a small part, producing possible disorganization of the whole system depending at what level the damage occurred. In summary, because the test used was unable to discriminate between the different facets of memory, it is not possible to state from this research

whether patients with MS, as a group, suffer differential aspects of memory loss. This is, therefore, still an open question, although there is evidence to suggest that memory ability in general is lowered in many MS patients.

In medical text descriptions of the symptom course in MS, there is little attention given to the cognitive and memory deficits that may occur. A recent example of this inaccuracy is contained in the book by Weiner and Goetz (1981) in which Stefoski states that "a decline of intellectual faculties is an extremely rare sign unless the disease is extremely severe and is predominantly of cerebral distribution" (p. 207). This present research, using a relatively unbiased sample of individuals with MS shows that 45% have a memory deficit which removes it from the "rare" designation. It is important that people who work in the area of MS are aware of the prevalence of memory deficits both from a theoretical as well as a practical base of knowledge.

Practical Implications

One of the practical implications of this study is that the whole area of memory ability should be taken into consideration in the planning of rehabilitation for people who are suffering from MS Many people with MS, are required by their physical disabilities to modify their personal life styles, their family commitments and their employment. If the individual has a moderate to severe memory deficit, this must be taken into

consideration in future planning. When people with MS, are living independently, their ability to manage their nutrition, medication and personal care needs will be affected if they have a severe memory deficit and this may lead to the necessity for a more dependent situation or even institutionalization. Families are frequently able to be more understanding and helpful when they realize that their relative with MS is not being purposely difficult or lazy when they fail to carry out their responsibilities because they have actually forgotten them. In the area of employment where one may be considering retraining for a less physically demanding job, the patient's ability to apprehend and retain new information must be assessed in order that they are not once again subjected to performance failures. For these reasons an assessment of memory functioning as an aid in rehabilitative decision-making is important.

In the specific rehabilitative process with MS patients who are undergoing a training process in perhaps the safe use of their wheelchair or perhaps in the preparation of food for their meal, it is important to assess which particular memory factors are preserved and which are affected. If they have, for example, a visual nonverbal deficit, the instructions and training process is better carried out with verbal instructions or even by cueing with an audio-verbal tape. Conversely, an individual who has most

difficulty with verbal material can be given diagrams to follow in order to learn the required method.

Very recently scientists and clinicians have begun to study the remediation of memory, particularly in an effort to help individuals who have suffered brain damage from various causes. Past efforts in mnemonics were largely confined to enabling people with normal memory to perform prodigious feats of memorization, but were of little practical use for an individual with memory impairment. Studies are now being conducted on the methods which might enable individuals to "handle, bypass or reduce their memory problems" (Wilson & Moffat, 1984, p. 1). These methods range from the use of internal (such as improved memory strategies) or external aids (such as computers) (Harris, 1984), to the employment of memory therapy groups (Wilson & Moffat, 1984).

All professional workers in the field of MS should be aware of the strong possibility that their patients/clients may be experiencing difficulty with their memory abilities. Also, they must be aware that this problem may be mild or severe. If it is severe it will interfere with patients' ability to learn and retain knowledge of how to cope with their disease and/or how to manage their own affairs with efficiency.

How and when to share possible future deficit information with a newly-diagnosed patient presents an ethical dilemma. Professionally ethical behavior requires that direct questions

must be answered with disclosure of the possibility of cognitive and memory loss as a result of the disease process. However, in the ethical decision-making process, it is the personal view of this author that the principle of responsible caring assumes precedence over the provision of statistical inferences about possible symptom occurrence. When a patient is asking "what are all the possible implications for me in having a diagnosis of MS", the psychologist has no way of knowing what will occur in this specific instance. The giving of information about possible cognitive loss opens up a whole new area of unpredictability for the patient which makes coping with whatever deficits actually exist even more difficult. Clinical experience shows that many newly-diagnosed MS patients suffer from serious anxiety and constantly monitor physical systems about whose functioning they are concerned. To add the dimension of possible memory loss to this area of anxiety would only harm the patient and it is difficult to see any ensuing benefit. At present there is no method of prevention and little treatment of memory deficits. When a specific patient and/or their family needs to deal with the actual occurrence of memory loss, then whatever remedial measures and counselling to enhance coping with the deficit, should be instituted.

Suggestions for Further Research

As mentioned previously, the search for a good and comprehensive instrument with which to assess memory must continue as knowledge of the strengths and weaknesses of an individual's memory will be the beginning point for any remediation procedures. The instrument must be designed to reflect the most current theoretical knowledge and to yield results that may be translated into practical terms. As Brooks and Lincoln (1984) point out, "one reason for assessing a patient is to identify the effect any deficits have on his everyday life" (p. 30).

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APPENDIX A

Tables and Figure

Table A1

Age, Education and IQ of the MS Sample

N = 100	Mean	S. D.	Range
Age	38.0	8.0	19 - 55
Education Level (Years)	13.0	1.0	7 - 24
IQ.(Verbal)	97.7	16.3	59 - 133

Table A2

Demographic Characteristics of MS Sample

N = 100	Categories
Sex	
Male	41
Female	59
Marital Status	
Single	23
Married	55
Separated	5
Divorced	16
Widowed	1
Occupation when Employed	
Professional, Technical	26
Manager, Clerical, Sales	39
Craftsmen, Foremen	8
Operatives, Service Workers, Farmers	19
Laborers	3
Not in Labor Force (homemakers, students)	5

Table A2 continued

Employment Status	
Working	31
Not Working	17
Not Working (due to MS)	52

Table A3

Disease Characteristics of MS Sample

N = 100	Mean	S. D.	Range
Years since Onset	15.0	8.0	2 - 40
Years since Diagnosis	10.2	6.3	1 - 32
Kurtzke Disability Scale	4.2	3.0	0 - 9
Kurtzke Functional Scales			
(a) Pyramidal	2.8	2.0	0 - 6
(b) Cerebellar	1.6	1.4	0 - 5
(c) Brainstem	1.1	1.1	0 - 4
(d) Sensory System	1.5	1.3	0 - 4
(e) Bowel/Bladder	1.8	1.6	0 - 6
(f) Vision	1.4	1.4	0 - 6
(g) Mental	0.4	0.7	0 - 3

Table A4

Means and Standard Deviations on the WMMB of the Normative Population

Scale	N	Mean	S. D.
Immediate Verbal Scales			
1. Visual Recall	304	17.32	4.73
2. Visual Recognition	278	13.34	2.83
3. Auditory Recall	301	12.40	2.30
4. Auditory Recognition	302	13.73	3.24
Immediate Nonverbal Scales			
5. Visual Recall	276	10.91	2.61
6. Visual Recognition	278	18.39	1.65
7. Auditory Recall	303	12.54	2.33
8. Auditory Recognition	300	23.28	4.08
Short-Term Verbal Scales			
9. Visual Recall	304	15.08	5.32
10. Visual Recognition	302	18.00	5.16
11. Auditory Recall	304	11.31	3.23
12. Auditory Recognition	304	14.56	5.41

Table A4 continued

Short-Term Nonverbal Scales			
13. Visual Recall	304	20.05	5.18
14. Visual Recognition	304	16.01	5.35
15. Auditory Recall	304	11.41	2.92
16. Auditory Recognition	302	13.36	2.32
Long-Term Verbal Scales			
17. Visual Recall	304	5.63	2.26
18. Visual Recognition	302	14.36	2.32
19. Auditory Recall	302	4.36	2.22
20. Auditory Recognition	304	5.77	2.26
Long-Term Nonverbal Scales			
21. Visual Recall	302	5.32	2.44
22. Visual Recognition	304	6.20	2.28
23. Auditory Recall	302	7.48	3.51
24. Auditory Recognition	276	15.91	2.21

Table A5

Mean and Standard Deviations on the WMMB of the MS Sample Standardized Against the Scores of Normative Population (numerical plot of Figure 2)

Variable	N	Mean	S. D.
1	100	-0.53	1.3
2	100	-0.62	1.6
3	100	-0.52	0.93
4	100	-0.83	1.4
5	100	-0.45	1.3
6	100	-1.60	2.3
7	100	-0.42	1.1
8	100	-0.35	1.3
9	100	-0.91	1.1
10	100	-1.10	1.3
11	100	-1.50	1.0
12	100	-1.00	1.0
13	100	-1.10	1.3
14	100	-1.20	0.9
15	100	-0.70	1.1
16	100	-0.30	1.1

Table A5 continued

17	100	-0.90	1.1
18	100	-0.70	1.4
19	100	-0.80	0.9
20	100	-1.00	1.0
21	100	-0.90	1.0
22	100	-1.10	0.9
23	100	-0.70	0.9
24	100	-0.20	1.2

Table A6

The Correlation Matrix of the 24 Subtests of the WPPB (Normative Group)

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
(1)	1	1.000																							
(2)	2	0.224	1.000																						
(3)	3	0.389	0.309	1.000																					
(4)	4	0.167	0.406	0.375	1.000																				
(5)	5	0.124	0.190	0.203	0.219	1.000																			
(6)	6	0.155	0.226	0.233	0.164	0.256	1.000																		
(7)	7	0.283	0.294	0.410	0.321	0.247	0.236	1.000																	
(8)	8	0.287	0.150	0.475	0.359	0.297	0.256	0.533	1.000																
(9)	9	0.310	0.536	0.383	0.454	0.318	0.294	0.343	0.295	1.000															
(10)	10	0.237	0.416	0.378	0.496	0.344	0.317	0.348	0.371	0.744	1.000														
(11)	11	0.323	0.307	0.328	0.372	0.341	0.270	0.382	0.338	0.389	0.422	1.000													
(12)	12	0.257	0.421	0.472	0.578	0.327	0.319	0.421	0.438	0.659	0.678	0.435	1.000												
(13)	13	0.251	0.364	0.360	0.377	0.342	0.347	0.460	0.424	0.579	0.565	0.370	0.572	1.000											
(14)	14	0.206	0.335	0.317	0.320	0.306	0.285	0.384	0.398	0.601	0.569	0.484	0.616	0.620	1.000										
(15)	15	0.318	0.304	0.301	0.343	0.488	0.395	0.337	0.330	0.378	0.462	0.405	0.487	0.436	0.453	1.000									
(16)	16	0.194	0.232	0.179	0.267	0.152	0.186	0.209	0.243	0.325	0.336	0.365	0.310	0.351	0.328	0.310	1.000								
(17)	17	0.210	0.493	0.346	0.482	0.332	0.291	0.323	0.319	0.843	0.693	0.373	0.650	0.562	0.543	0.347	0.309	1.000							
(18)	18	0.225	0.185	0.241	0.243	0.118	0.162	0.234	0.329	0.353	0.317	0.234	0.314	0.314	0.348	0.220	0.198	0.367	1.000						
(19)	19	0.238	0.417	0.430	0.566	0.330	0.285	0.447	0.430	0.704	0.699	0.436	0.666	0.627	0.612	0.459	0.344	0.677	0.391	1.000					
(20)	20	0.176	0.361	0.485	0.505	0.287	0.280	0.426	0.473	0.591	0.652	0.370	0.820	0.537	0.523	0.343	0.234	0.600	0.322	0.607	1.000				
(21)	21	0.230	0.250	0.337	0.442	0.290	0.285	0.387	0.355	0.573	0.563	0.387	0.555	0.627	0.605	0.475	0.256	0.536	0.337	0.630	0.545	1.000			
(22)	22	0.218	0.259	0.340	0.429	0.294	0.264	0.360	0.358	0.557	0.570	0.420	0.599	0.632	0.808	0.444	0.271	0.543	0.302	0.614	0.554	0.635	1.000		
(23)	23	0.217	0.307	0.251	0.393	0.202	0.182	0.386	0.346	0.385	0.360	0.364	0.412	0.400	0.454	0.316	0.293	0.355	0.278	0.433	0.362	0.392	0.421	1.000	
(24)	24	0.221	0.231	0.177	0.220	0.240	0.203	0.141	0.251	0.250	0.323	0.294	0.302	0.332	0.310	0.270	0.381	0.245	0.162	0.352	0.231	0.244	0.342	0.142	1.000

Table A7

The Proportion of Variance Accounted for by the Factor Structure of the WMMB (Normative Group)

Factor	Eigenvalues	Cumulative Proportion
1	10.05	.42
2	1.44	.48
3	1.30	.53
4	1.08	.58
5	1.00	.62
6	.88	.66
7	.86	.69
8	.80	.73
9	.74	.76
10	.65	.78
11	.63	.81
12	.59	.83
13	.53	.86
14	.48	.88
15	.44	.90
16	.41	.91
17	.41	.93

Table A7 continued

18	.36	.94
19	.32	.96
20	.28	.97
21	.25	.98
22	.19	.99
23	.14	.99
24	.12	1.00

Table A8

The Residual Correlation Matrix for 24 Subtests of the WPPSI in the Normative Population with Factor 1 Removed

Test	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0.84																							
2	0.01	0.70																						
3	0.17	0.00	0.86																					
4	-0.09	0.06	0.02	0.60																				
5	-0.06	-0.06	-0.06	-0.06	0.90																			
6	-0.02	-0.01	-0.01	-0.11	0.16	0.31																		
7	0.05	-0.02	0.13	-0.05	-0.02	-0.01	0.87																	
8	0.07	-0.16	0.15	0.01	-0.08	0.00	0.20	0.57																
9	-0.01	0.10	-0.09	-0 06	-0.05	-0.06	-0.12	-0.17	0.36															
10	-0.08	-0.02	-0.07	-0.01	-0.03	-0.03	-0.11	-0.09	-0.10	0.36														
11	0.08	-0.02	-0.01	-0 01	0.08	0.01	0.34	-0.01	-0.08	-0.06	0.63													
12	-0.07	-0.02	0.01	0 05	-0.08	-0.04	-0.06	-0.04	-0.01	0.02	-0.08	0.31												
13	-0.05	-0.05	-0.08	-0 12	-0.01	0.02	0.02	-0.01	-0.03	-0.04	-0.09	-0.06	0.42											
14	-0.02	-0.06	-0.12	-0.10	-0.06	-0.05	-0.06	-0.05	-0.02	-0.05	-0.01	-0.02	0.03	0.04										
15	0.07	-0.13	-0.05	-0 05	0.20	0.13	-0.02	-0.02	-0.11	-0.03	0.04	-0.02	-0.03	-0.02	0.52									
16	0.01	-0.02	-0.07	-0 02	-0.05	-0.01	-0.05	-0.02	-0.04	-0.03	0.09	-0.07	0.01	-0.02	0.03	0.79								
17	-0.09	0.07	-0.09	-0 03	-0.03	-0.04	-0.12	-0.13	0.22	0.08	-0.09	0.02	-0.03	-0.05	-0.13	-0.04	0.60							
18	0.04	-0.06	-0.02	-0.05	-0.09	-0.04	-0.03	0.06	-0.01	0.05	-0.04	-0.07	-0.04	-0.01	-0.26	-0.01	0.01	0.79						
19	-0.09	-0.04	-0.04	0 04	-0.06	-0.08	-0.03	-0.05	0.04	0.03	-0.08	-0.02	-0.01	-0.03	-0.05	-0.03	0.03	0.03	0.31					
20	-0.13	-0.05	0.04	0 02	-0.07	-0.05	-0.01	0.03	-0.02	0.04	-0.09	0.14	-0.04	-0.07	-0.12	-0.11	0.01	-0.03	-0.03	0.42				
21	-0.07	-0.05	-0.08	-0 04	-0.04	-0.06	-0.04	-0.07	-0.02	-0.03	-0.56	-0.05	0.06	0.03	0.02	-0.03	-0.04	-0.01	-0.01	-0.02	0.44			
22	-0.09	-0.06	-0.09	-0 06	-0.06	-0.06	-0.08	-0.08	0.08	-0.04	-0.04	-0.03	0.05	0.22	-0.02	-0.08	-0.05	-0.05	-0.05	-0.03	0.06	0.42		
23	-0.01	0.00	-0.09	-0 06	-0.05	-0.08	0.08	0.02	-0.09	-0.09	0.02	-0.05	-0.03	0.01	-0.03	0.04	-0.08	0.02	0.02	-0.05	-0.03	-0.01	0.68	
24	0.50	-0.01	-0.08	0 04	0.04	0.02	-0.10	0.01	-0.08	-0.02	0.04	-0.05	0.01	-0.02	0.01	0.19	-0.08	-0.03	-0.03	-0.09	-0.07	0.02	-0.09	0.82

Table A9

Canonical Pattern Matrix for Eight Best Separator Variables of Six Clusters

	1	2	3	4	5
% Variance	45.14	74.21	85.82	83.78	100.00
Variable 02	.53	.15	.02	-.03	.76
03	.33	-.39	-.87	-.36	-.43
06	.23	.98	.15	.08	-.06
08	-.55	.46	-.56	.72	.67
11	-.80	.35	.22	.52	.35
14	-.81	-.06	.80	.54	.55
18	.83	-.44	.11	.28	.35
24	.87	-.10	.03	.79	-.55

Table A10

Canonical Structure Weights and Extension Analysis Weights for First two Canonical Variates (for eight best separator variables of six clusters)

Variable		
1	.2657	.3251
2	.6867	.3042
3	.1270	.2430
4	.4491	.4787
5	.3517	.4901
6	.3994	.8408
7	.0936	.3956
8	.1515	.4566
9	.3766	.3512
10	.3128	.4949
11	-.2994	.4526
12	.2774	.3829
13	.3137	.5128
14	.2341	.3782
15	.4325	.3717
16	.2867	.1217

Table A10 continued

17	.3899	.3850
18	.7487	-.1059
19	.4130	.2671
20	.3269	.4595
21	.2238	.4433
22	.1929	.3672
23	.3076	.2214
24	.6385	.1140

Table A11

A Summary of the Contribution of Elevation, Scatter and Shape (the Interaction of Shape and Scatter) to the Full Variation of the WMMB

	Percentage
Elevation	54.33
Scatter	2.89
Shape	42.78
TOTAL	100.00%

Table A12

The Relationship Between Measures of Elevation, Scatter and Shape

	Elevation	Scatter	Shape 1
Elevation			
Scatter	-.33		
Shape 1	.44	-.41	
Shape 2	.52	-.28	.00

Table A13

A Cross Classification of Cluster Membership with the Normal/Abnormal Dimension According to Elevation

	Abnormal	Normal	
Normality	45	55	
Cluster 1	12	45	57
Cluster 2	4	5	9
Cluster 3	29	5	34

Table A14

Path Analysis of Memory: Derivation of Path Coefficients (Multiple Regression of Memory) (Part I)

	Regression Coefficient	Standard Error	T-Statistic	Significance Level
Constant	0.00	0.057	0.00	1.00
Sex	0.12	0.059	2.08	0.040
Age	-0.21	0.067	- 3.17	0.002
Years Since Onset	-0.005	0.071	- 0.07	0.94
Kurtzke Total Score	-0.29	0.066	- 4.39	0.000
IQ	0.62	0.059	10.53	0.0000

Table A15

Path Analysis of Memory: Derivation of Path Coefficients (Multiple Regression of Memory) (Part II)

	Regression Coefficient	Standard Error	T-Statistic	Significance Level
Constant	0.00	0.098	0.00	1.0
Kurtzke Total Score	-0.251	.111	-2.25	.028
Age	.102	.116	0.880	.381
Years Since Onset	-0.101	.122	-0.829	.408
Sex	-0.0136	.102	-0.1325	.894

Table A16

Path Analysis of Memory: Derivation of Path Coefficients (Multiple Regression of Memory) (Part III)

	Regression Coefficient	Standard Error	T-Statistic	Significance Level
Sex	-.259	.0899	-2.888	.0048
Years Since Onset	.352	.0156	3.332	.0012
Age	.0763	.1056	.723	.4715

Table A17

Path Analysis of Memory: Derivation of Path Coefficients (Multiple Regression of Memory) (Part IV)

	Regression Coefficient	Standard Error	T-Statistic	Significance Level
Constant	-.000	.0855	0.000	1.000
Age	.5251	.0859	6.108	.0000

Table A18

Residual Correlation Matrix of the Six Demographic IQ and Disease Variables

	Sex	Age	Years Since Onset	Severity	Intelligence
Sex					
Age	-.02				
Years Since Onset	.02				
Severity			-.01		
Intelligence	-.02	.05	-.09		
Memory Elevation					

The unfilled cells are zero by definition and to have significance <0.05, r must be greater than .20.

Table A19

Correlation Between Factors 1 and 2 and the Kurtzke Disability Scale Part I

	Factor 1	Factor 2
Overall Scale	.9287	.1920

r = .05 = .1966

Table A20

Regression Analysis: Prediction of Elevation (Factor 1) by Four Memory Tests Most Related to Shape

	D.F.	Sum of Squares	Mean Squares	F-Stat	Significance
Regression	4	132.11	33.028	75.49	.000
Error	95	41.56	.437		
Total	99	173.67			

Multiple R = .8721

Variable	Coefficient	Std. Error	T-Stat	Significance
Constant	-.498	.086	-5.816	.000
2	.246	.056	4.385	.000
6	.326	.035	9.388	.000
18	.169	.065	2.606	.011
24	.001	.058	0.016	.987

Table A21

Regression Analysis: Prediction of Shape 1 by Four Memory Tests Most Related to Shape

	D.F.	Sum of Squares	Mean Squares	F-Stat	Significance
Regression	4	293.58	73.395	61.763	.000
Error	95	112.89	1.188		
Total	99	406.47			

Multiple R = .8498

Variable	Coefficient	Std. Error	T-Stat	Significance
Constant	1.357	.1412	9.606	.000
2	.4791	.0924	5.184	.000
6	-0.0299	.0572	-0.524	.602
18	.5677	.1071	5.3005	.000
24	.4052	.0962	4.213	.0001

Table A22

Regression Analysis: Prediction of Shape 2 by Four Memory Tests Most Related to Shape

	D.F.	Sum of Squares	Mean Squares	F-Stat	Significance
Regression	4	251.28	62.825	135.97	.000
Error	95	43.89	.46		
Total	99	295.17			

Multiple R = .9226

Variable	Coefficient	Std. Error	T-Stat	Significance
Constant	.0434	.0881	.4928	.623
2	.0206	.0576	.3580	.721
6	.7125	.0357	19.970	.000
18	-.4409	.0668	- 6.602	.000
24	.1097	.0599	- 1.828	.071

Table A23

Regression Analysis: Prediction of Scatter by Four Memory Tests Most Related to Shape

	D.F.	Sum of Squares	Mean Squares	F-Stat	Significance
Regression	4	249.53	62.38	19.66	.0000
Error	95	301.44	3.17		
Total	99	550.97			

Multiple R = .6730

Variable	Coefficient	Std. Error	T-Stat	Significance
Constant	.5371	.2309	2.326	.022
2	.2776	.1510	1.838	.069
6	-.4365	.0935	-4.668	.000
18	-.2586	.1750	-1.478	.143
24	-.6120	.1572	-3.893	.000

Table A24

A Two-Way Cross Tabulation of Poor Versus Good Memory with Disease Course Categorization

Disease Course	Totals	Poor Memory	Good Memory
Relapsing	38	8	30
Relapsing/Progressive	31	18	13
Progressive	31	19	12
Totals	100	45	55

χ-square = 14.267

$p<.0008$

Table A25

A Two Way Cross Tabulation of Gender with Disease Course Categorization

Disease Course	Totals	Poor Memory	Good Memory
Relapsing	38	11	27
Relapsing/Progressive	31	15	16
Progressive	31	15	16
Totals	100	41	59

χ-square = 3.6806

p = n.s.

Table A26

A Two Way Cross Tabulation of Marital Status with Disease Course Categorization

Disease Course	Totals	Single	Married	Separated	Divorced	Widowed
Relapsing	38	10	20	4	3	1
Relapsing/ Progressive	31	7	15	0	9	0
Progressive	31	6	20	1	4	0
Totals	100	23	55	5	16	1

χ-square = 11.893

p = n.s.

Table A27

A Two Way Cross Tabulation of Occupational Category (when employed) with Disease Course Categorization

Disease Course	Totals	Professional Technical	Manager Clerical	Craftsman Foreman	Farmer Service Worker	Laborer	Homemaker Student
Relapsing	38	12	16	2	5	1	2
Relapsing/ Progressive	31	6	11	4	6	2	2
Progressive	31	8	12	2	8	0	1
Totals	100	26	39	8	19	3	5

χ- square = 6.5049

p = n.s.

Table A28

A Two-Way Cross Tabulation of Present Employment Status with Disease Course Categorization

Disease Course	Totals	Working	Not Working	Not Working due to MS
Relapsing	38	17	10	11
Relapsing/ Progressive	31	8	4	19
Progressive	31	6	3	22
Totals	100	31	17	52

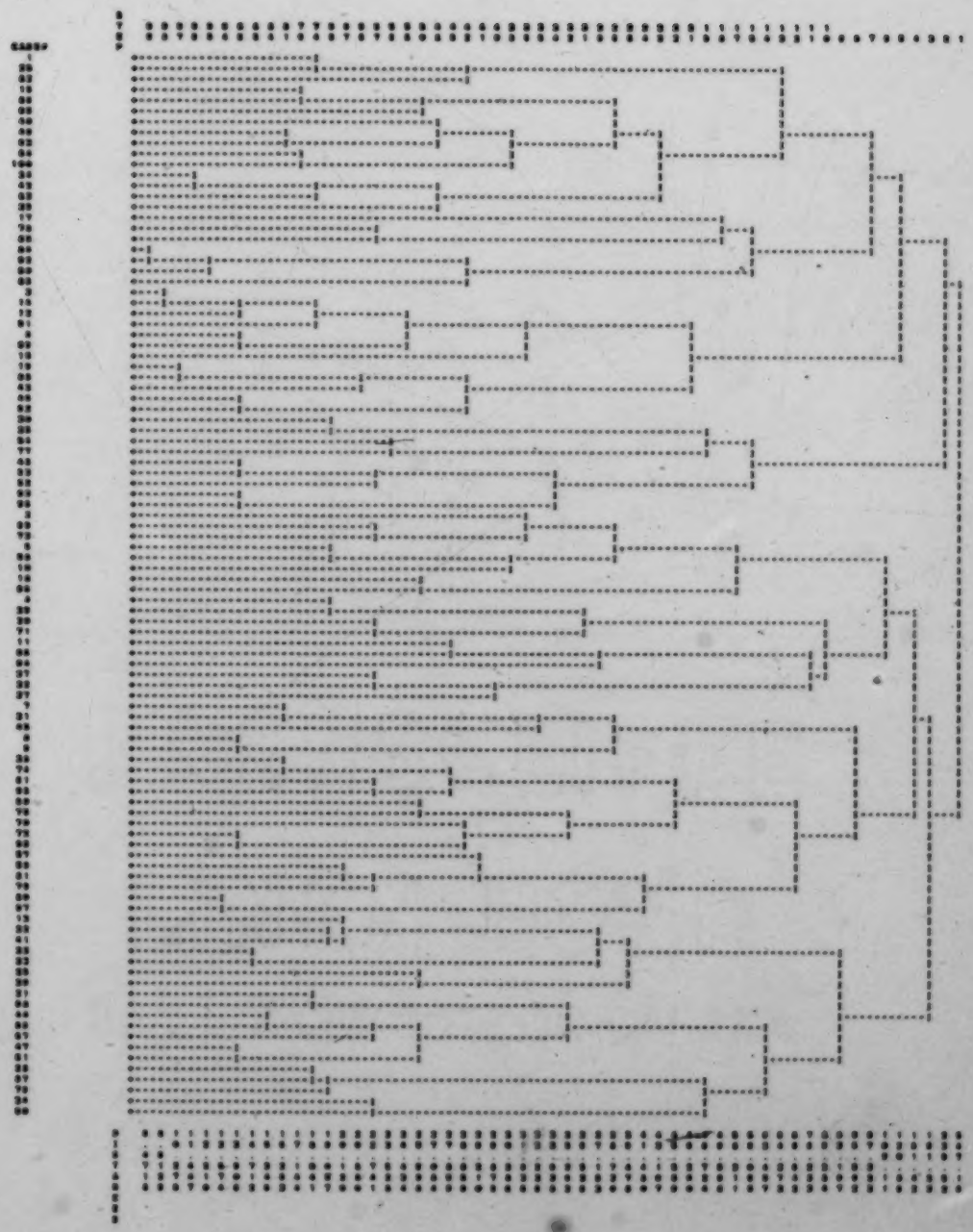
p = n.s.

Table A29

Stepwise Discriminant Function Analysis of the Disease Course Distinction (Final Step)

Variable	F-Stat	Significance	Relapsing	Relapse/ Progressive	Progressive
Constant			-11.770	-12.960	-18.419
Age	7.320	p<.0011	.6450	.61028	.7445
K.D.S. T Disability	36.368	p<.0000	.0100	.0818	.1019

Figure A1. Cluster analysis.



APPENDIX B

Visual Representations of 100 Individual Standardized Test Scores

Figure B1.

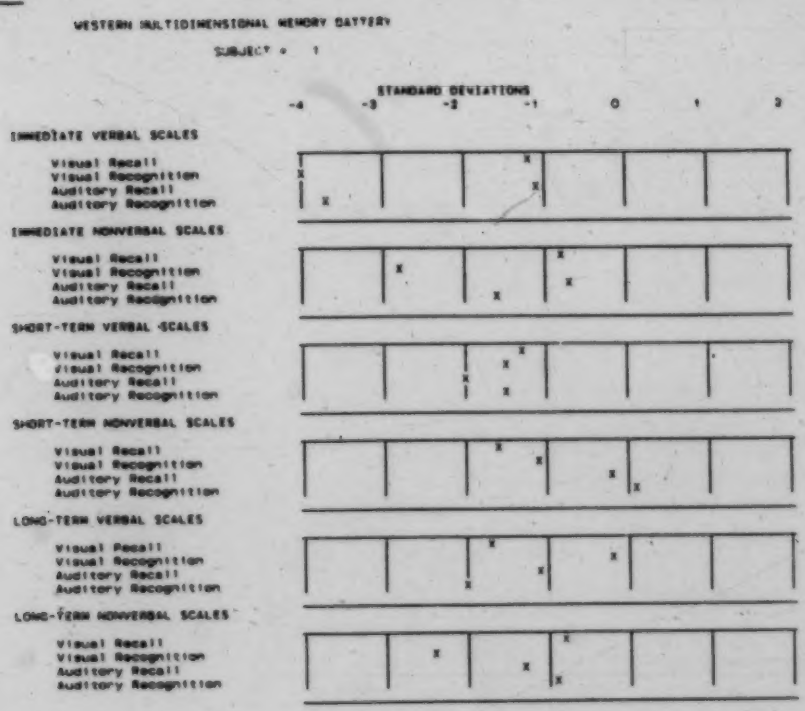


Figure B2.

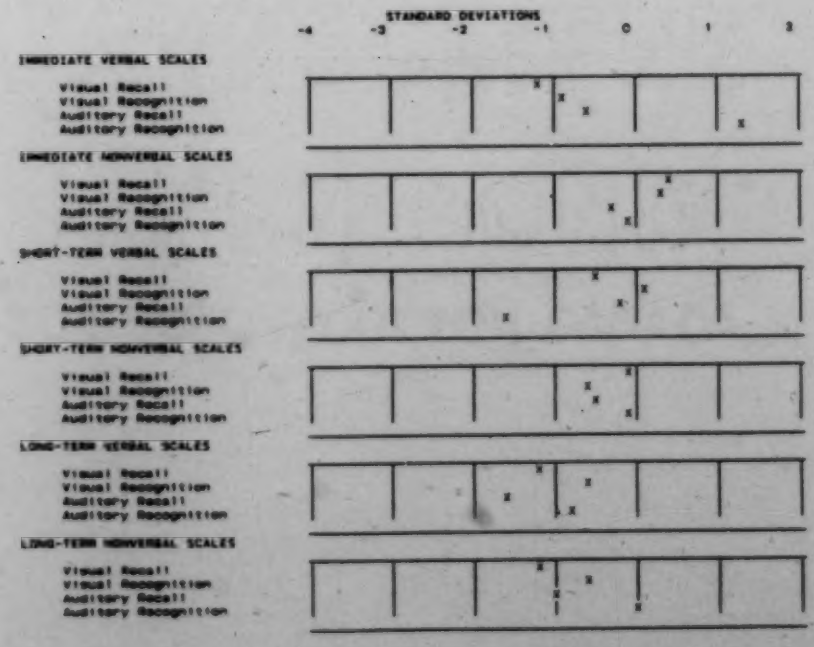
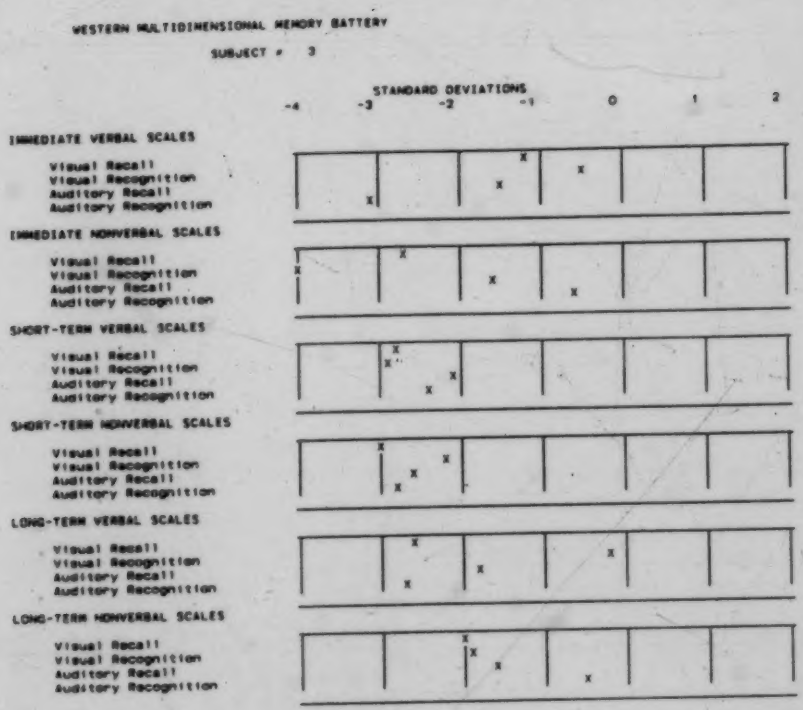


Figure B3.



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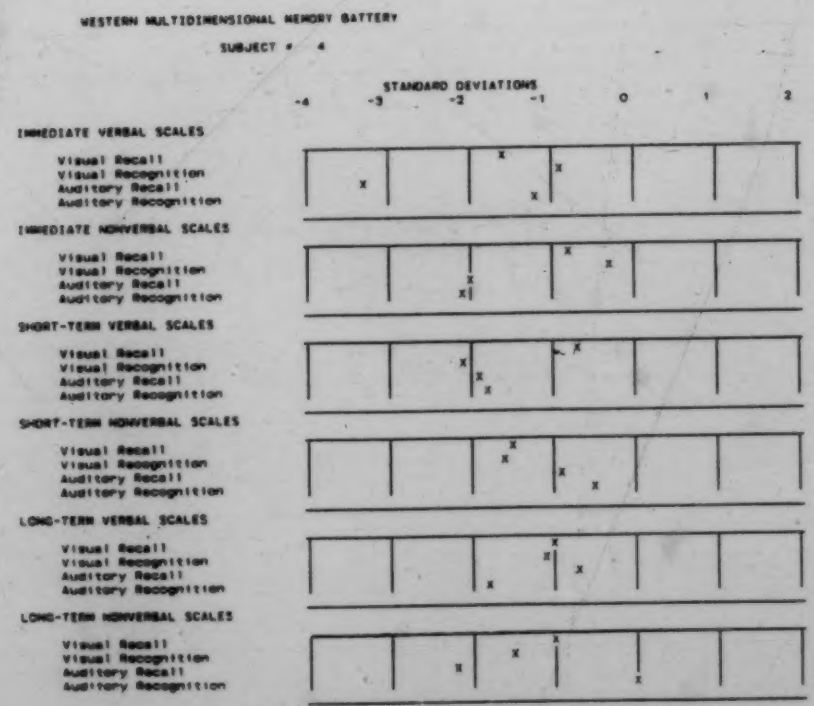

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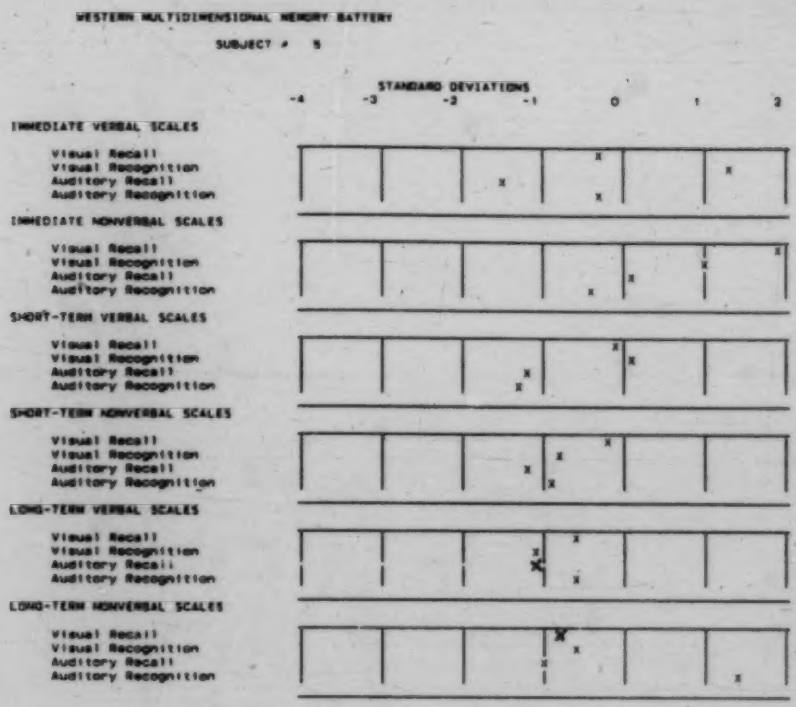

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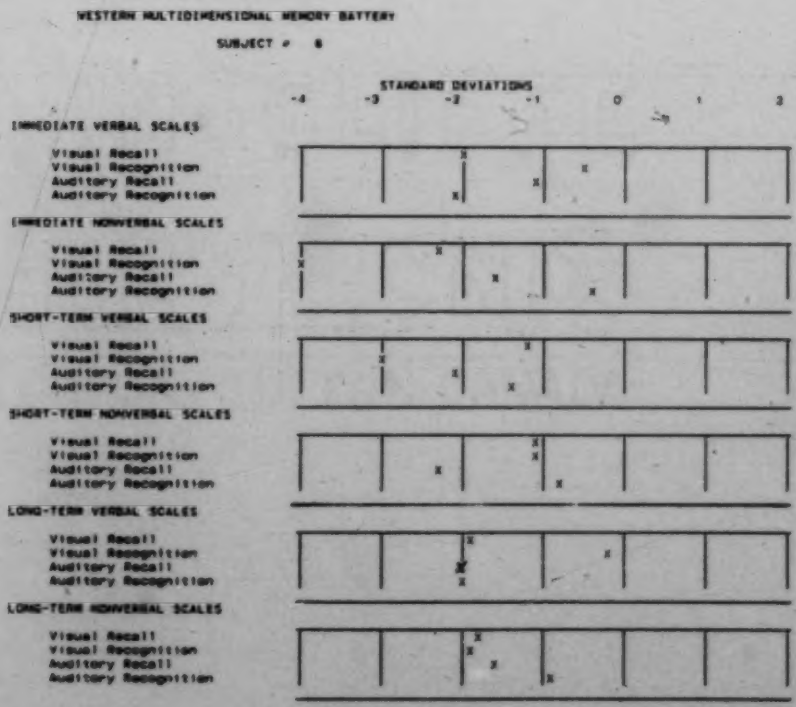

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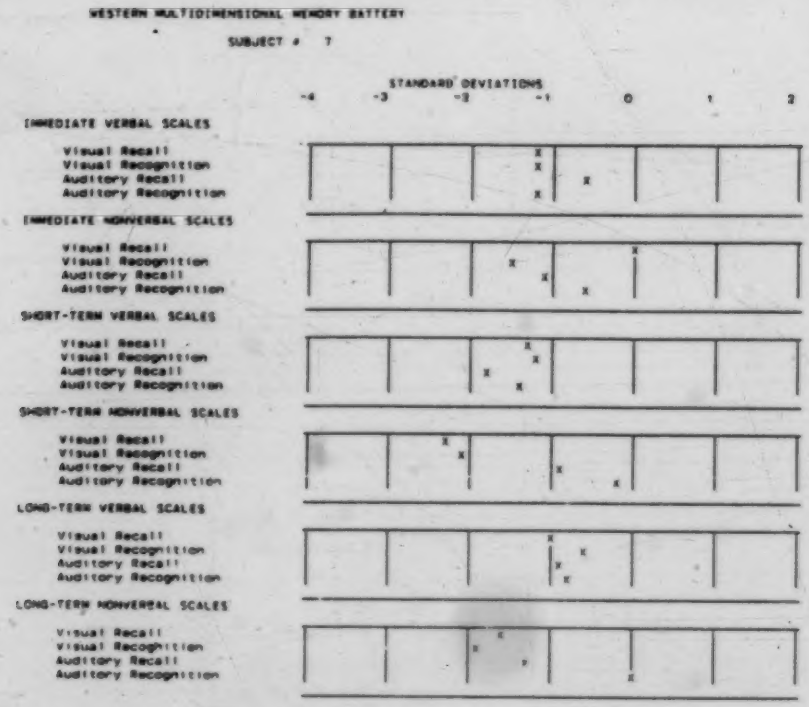

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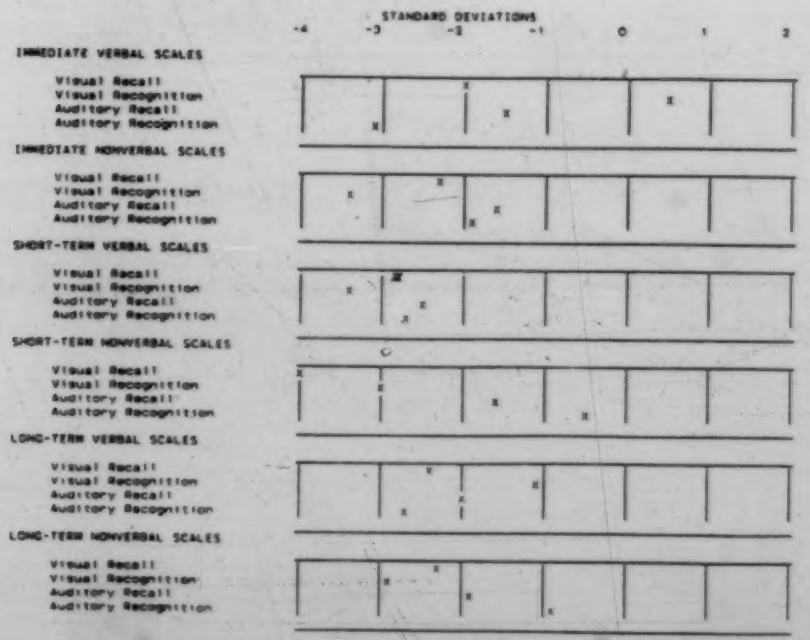

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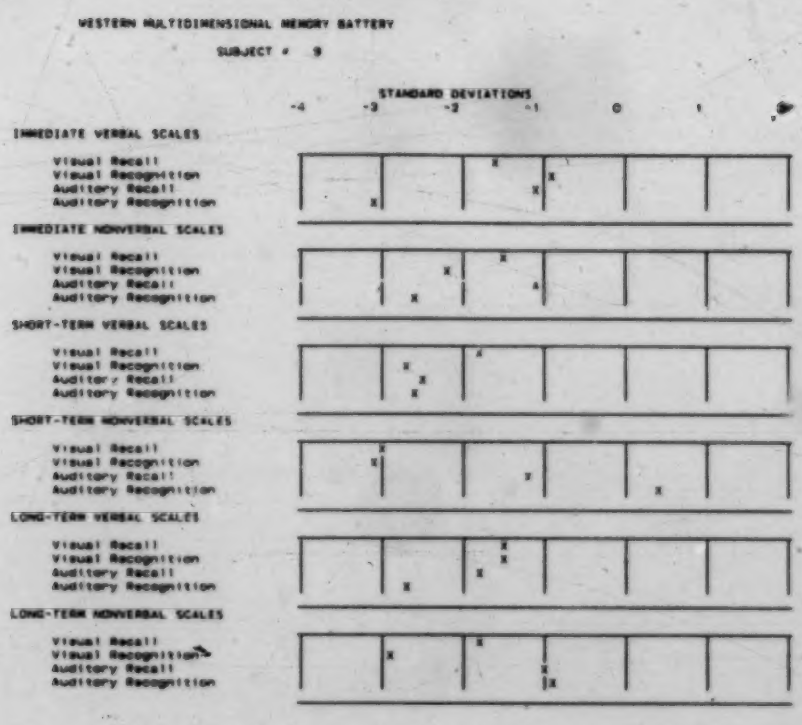

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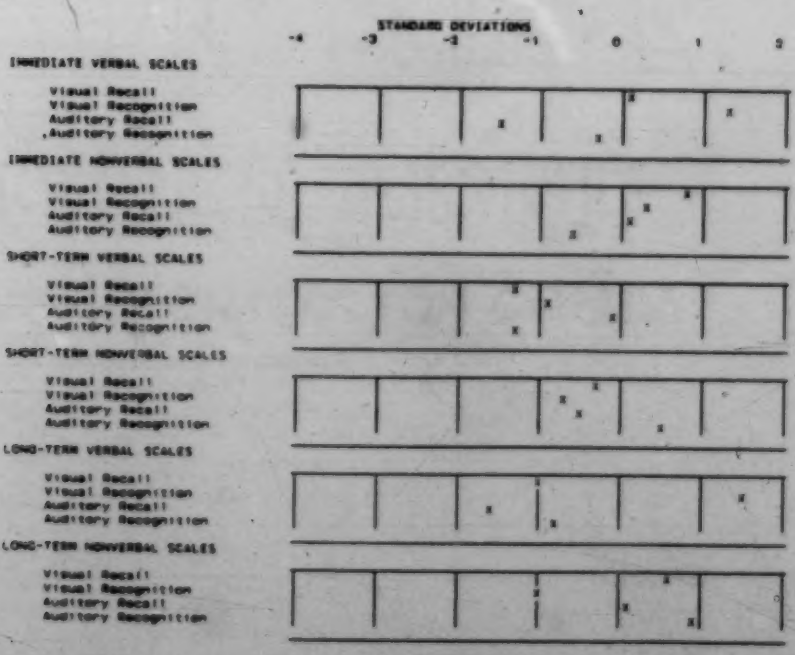

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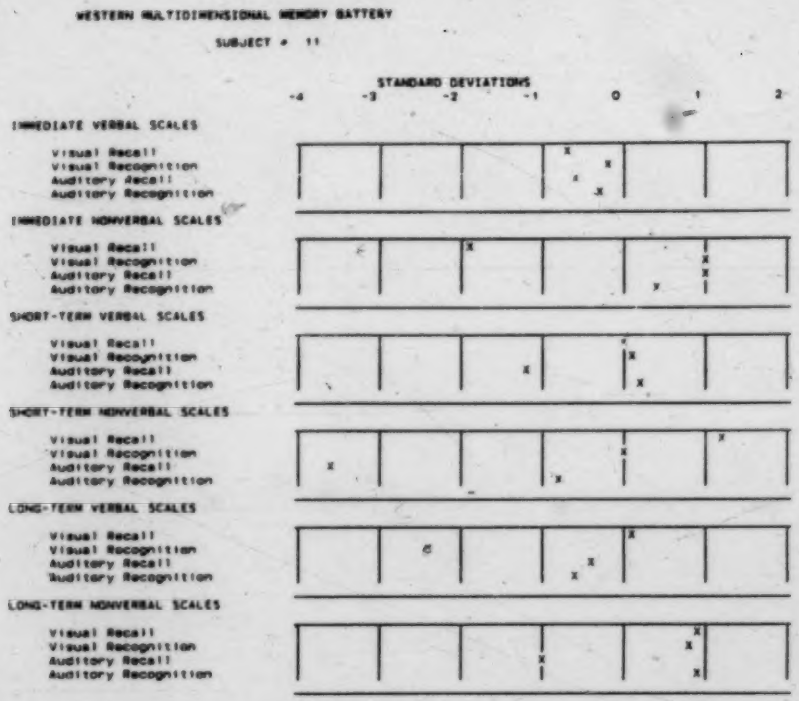

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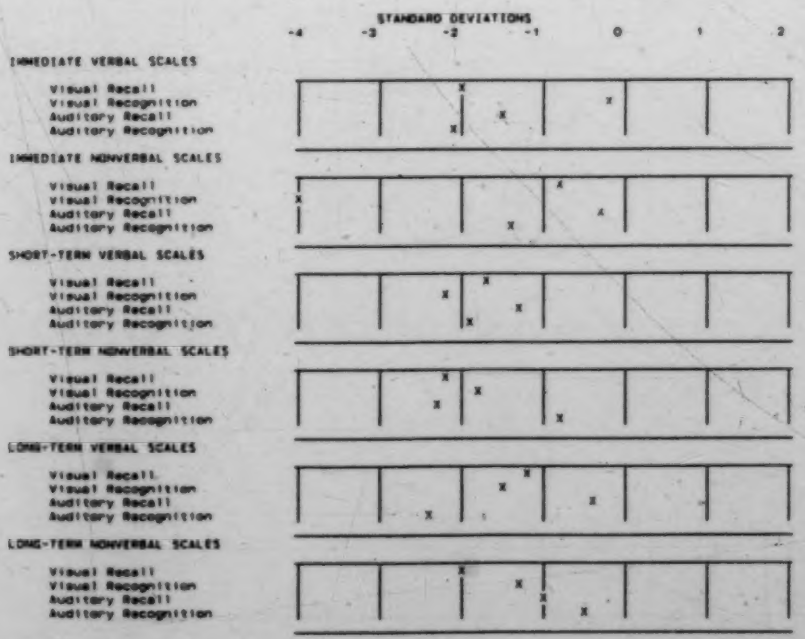

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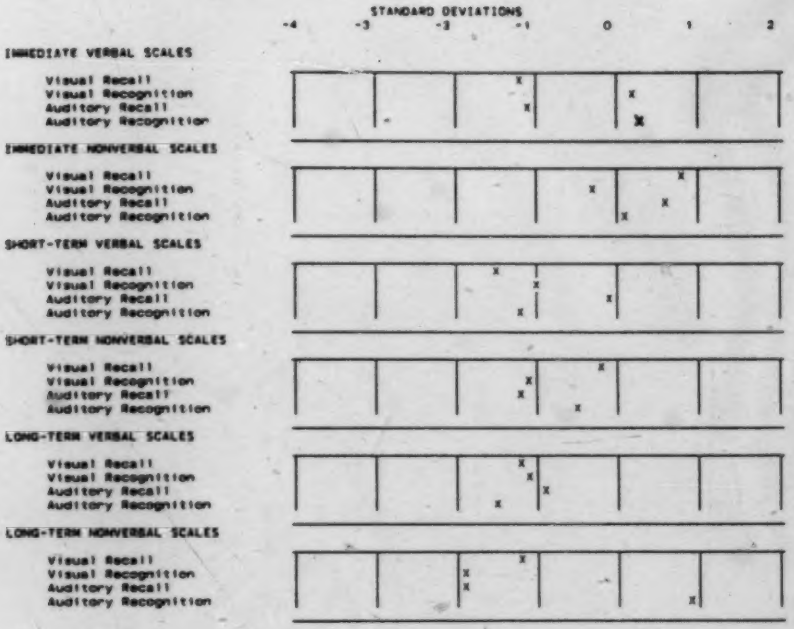

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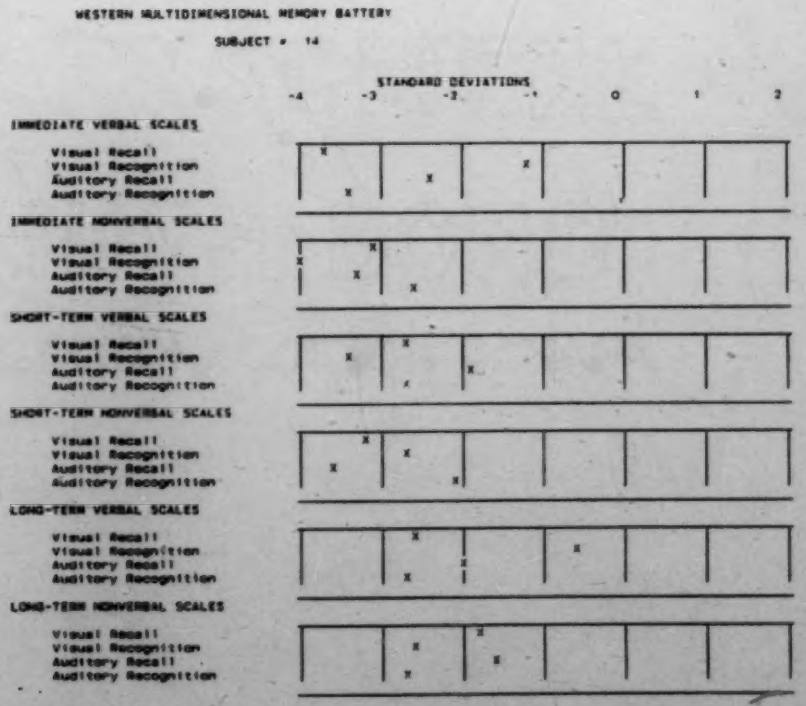

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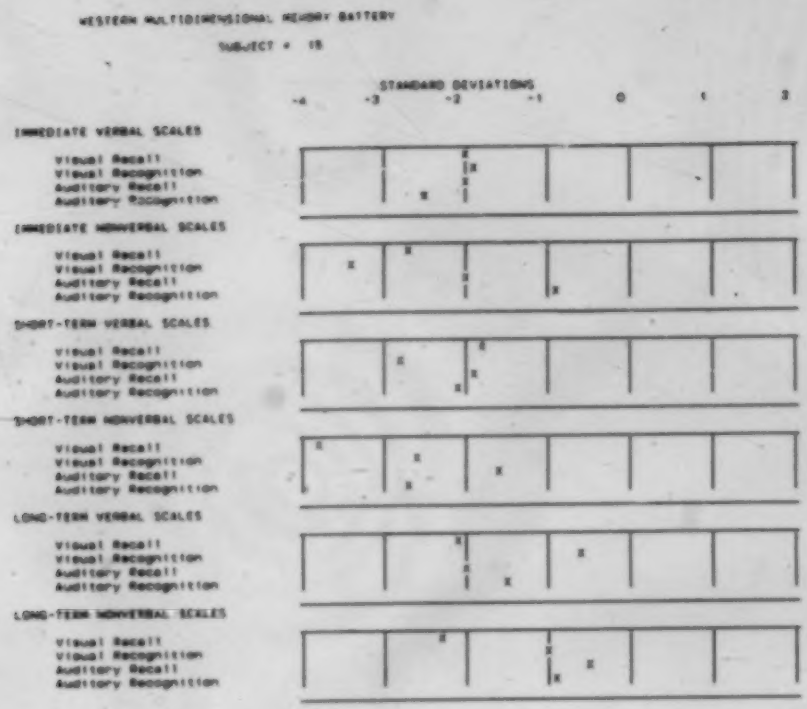

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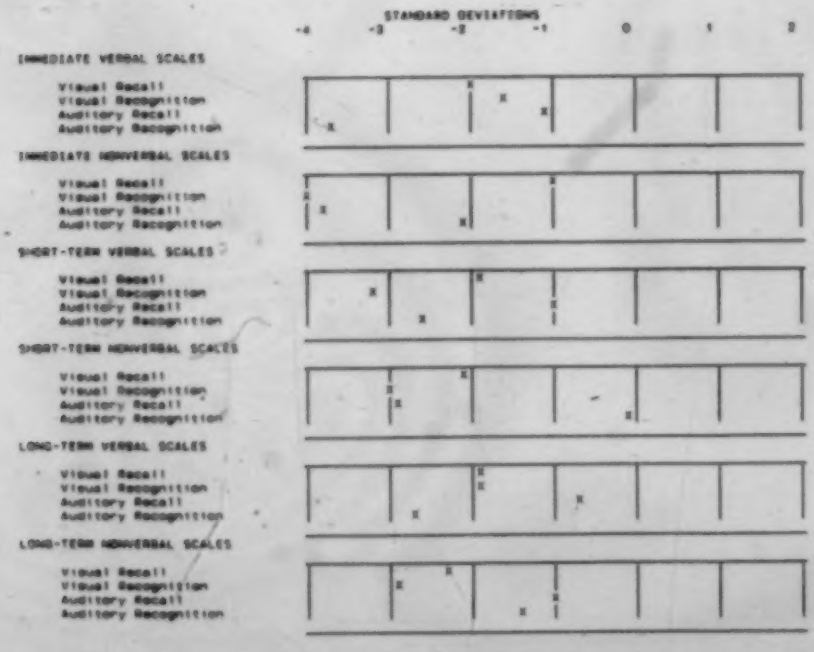

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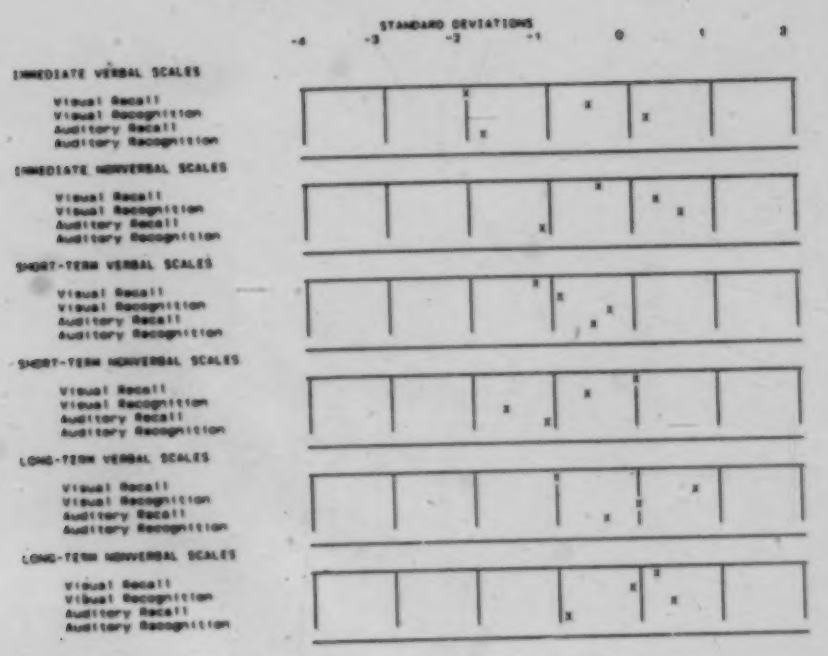

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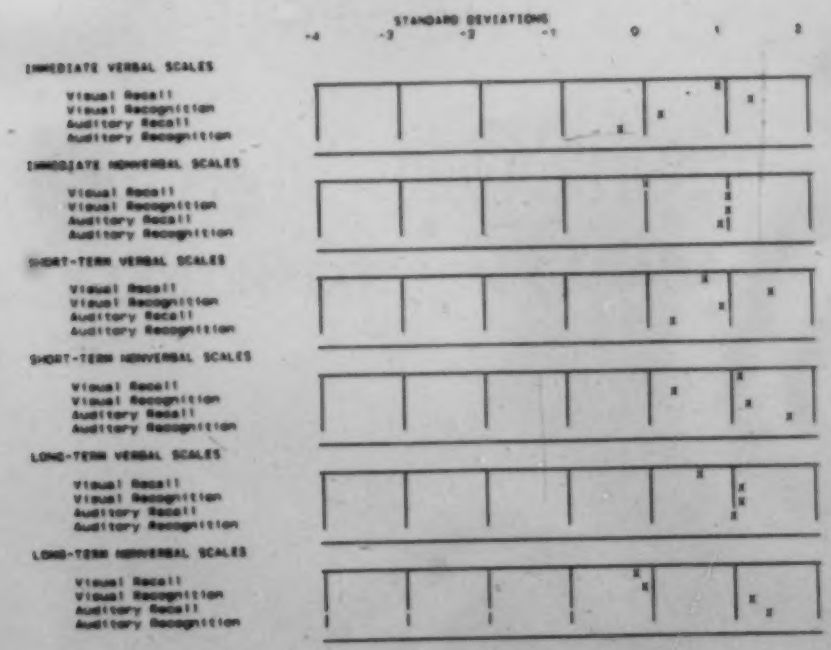

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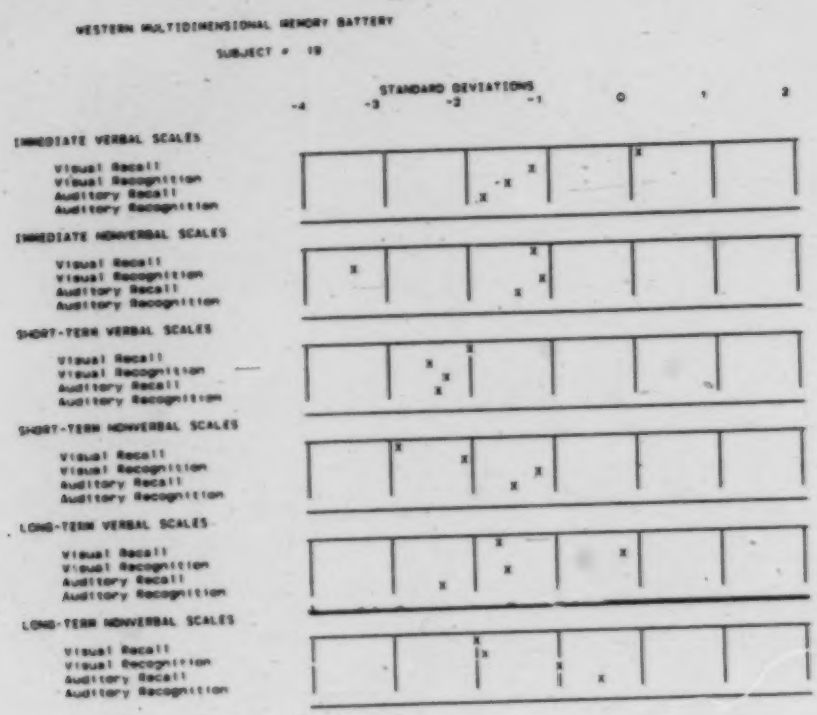

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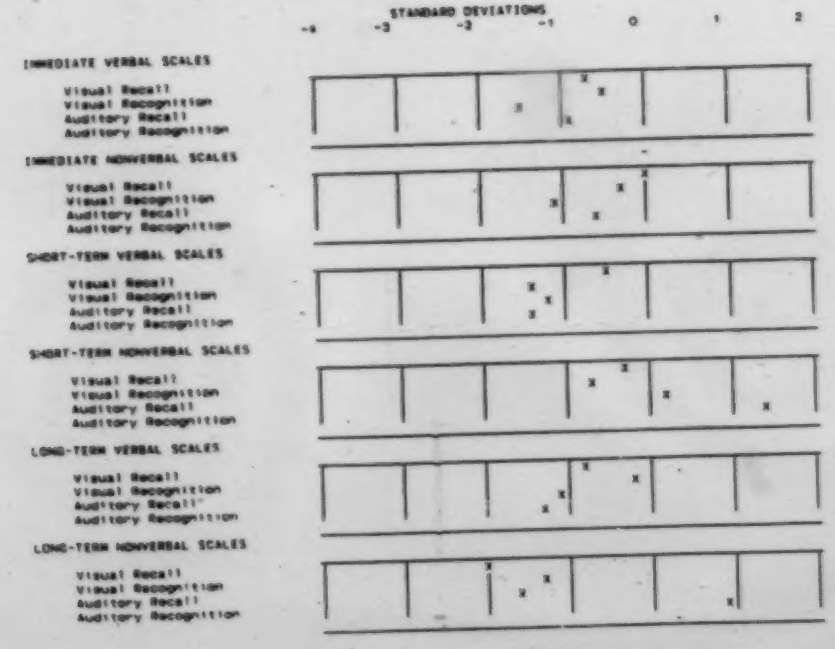

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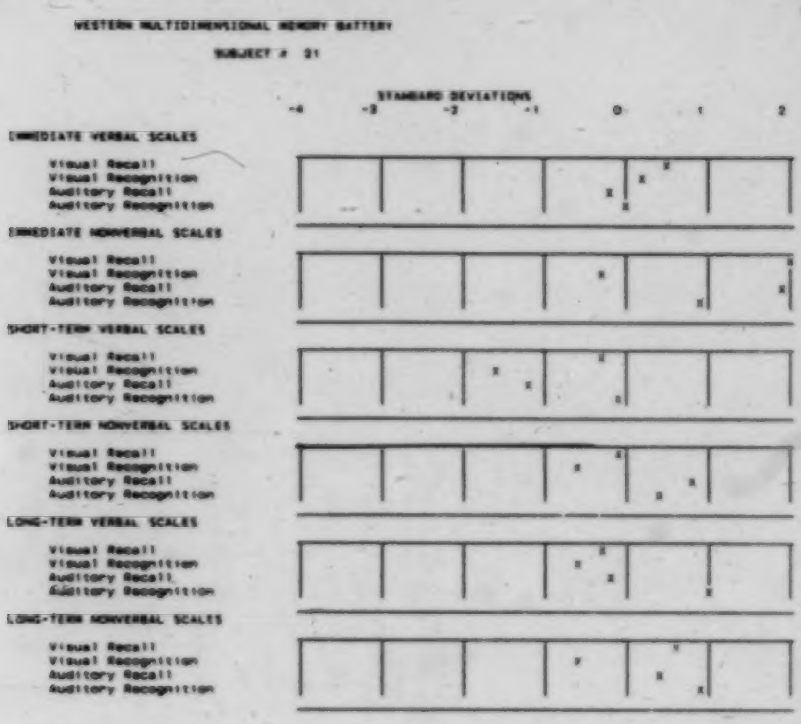

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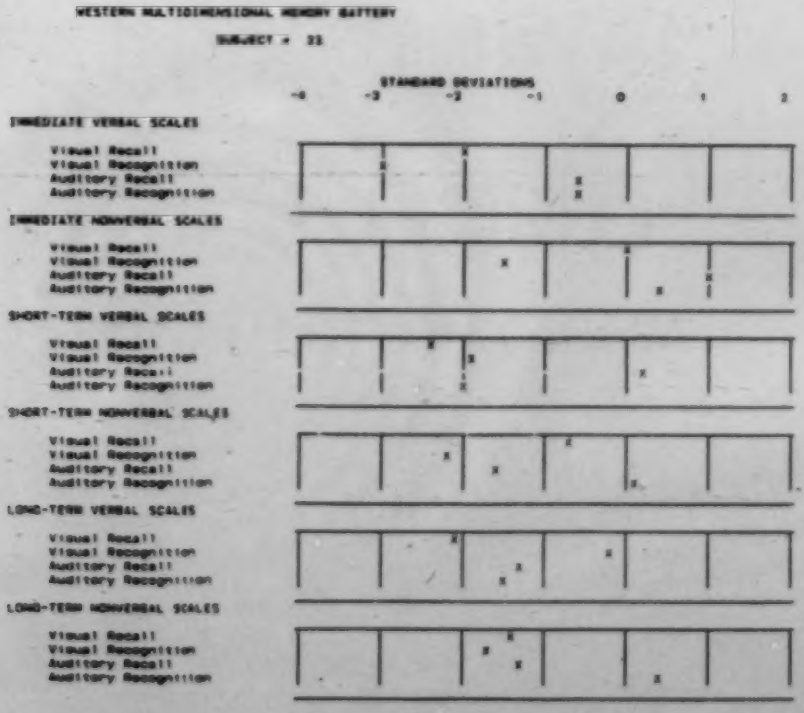

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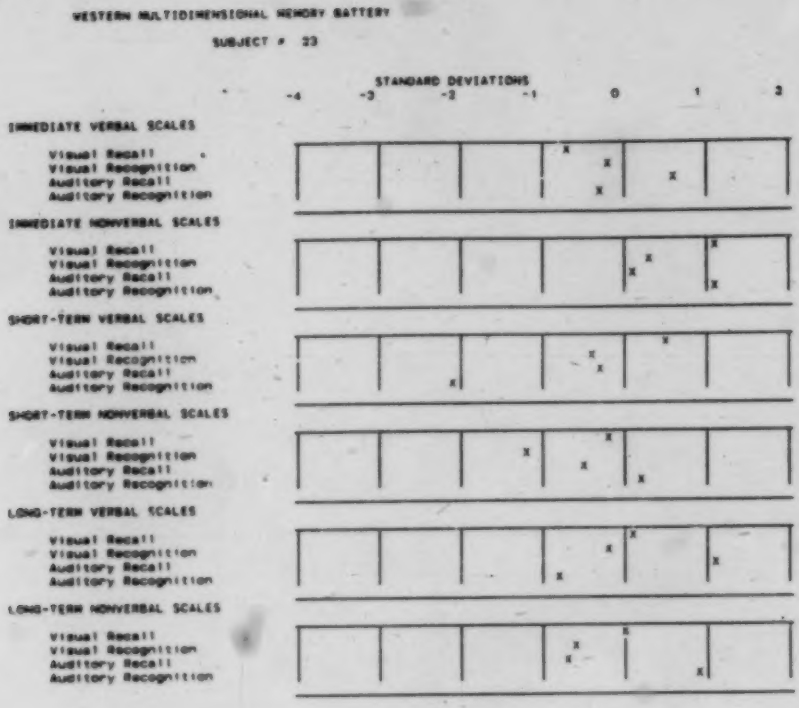

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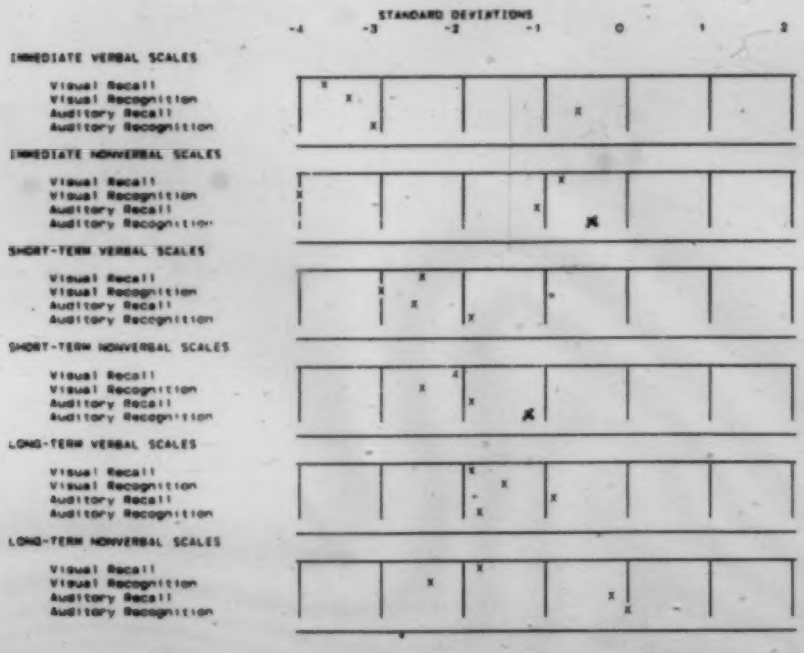

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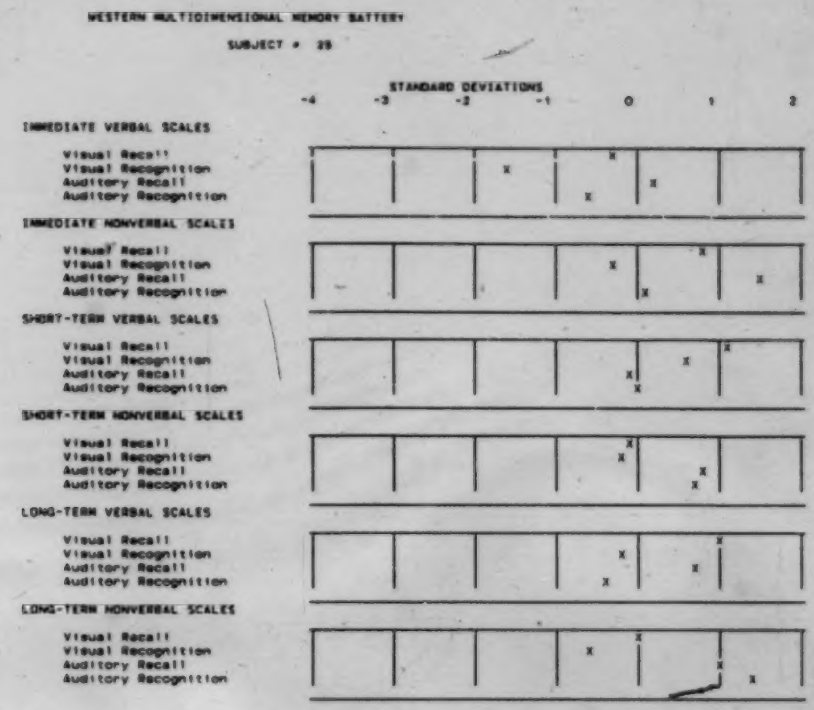

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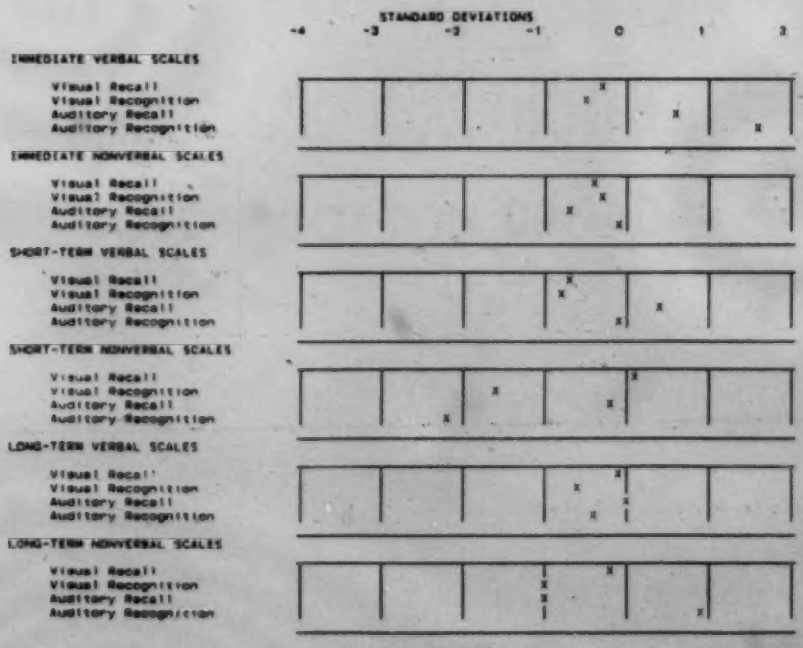

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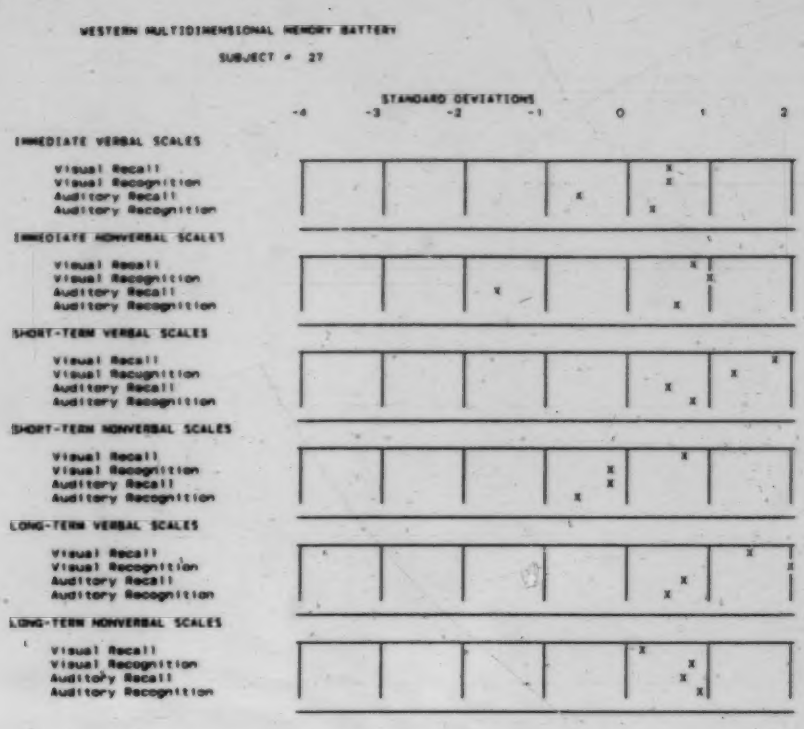

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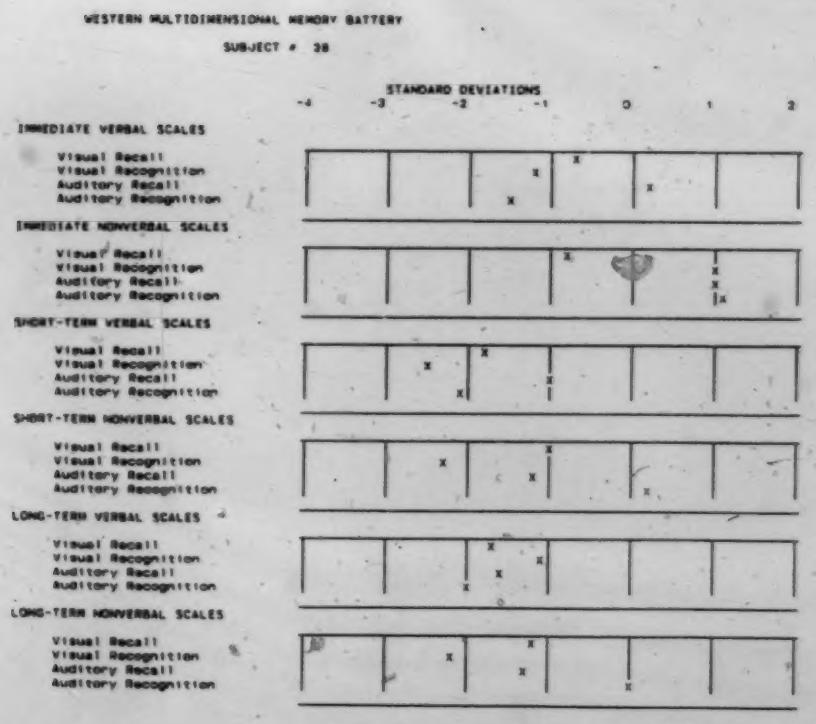

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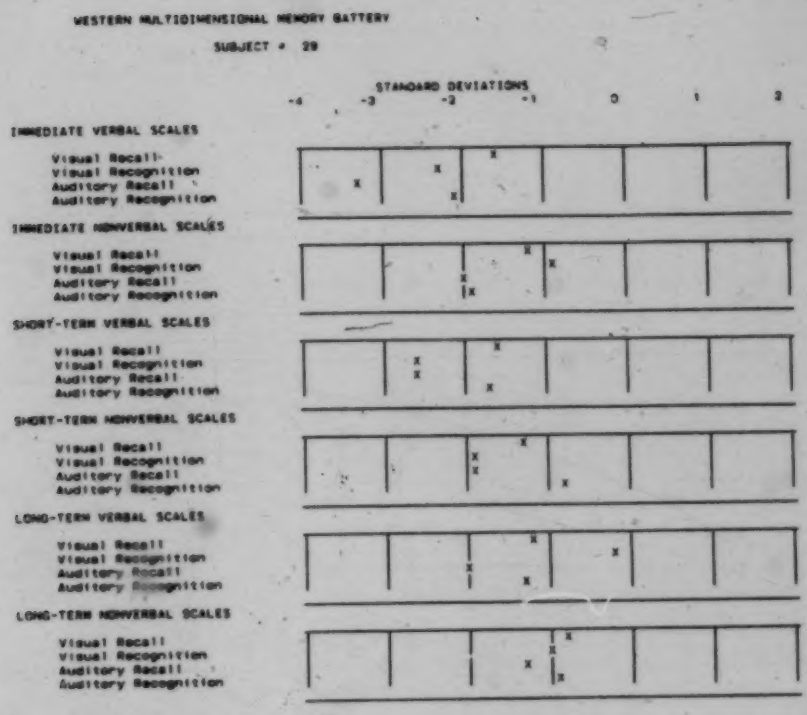

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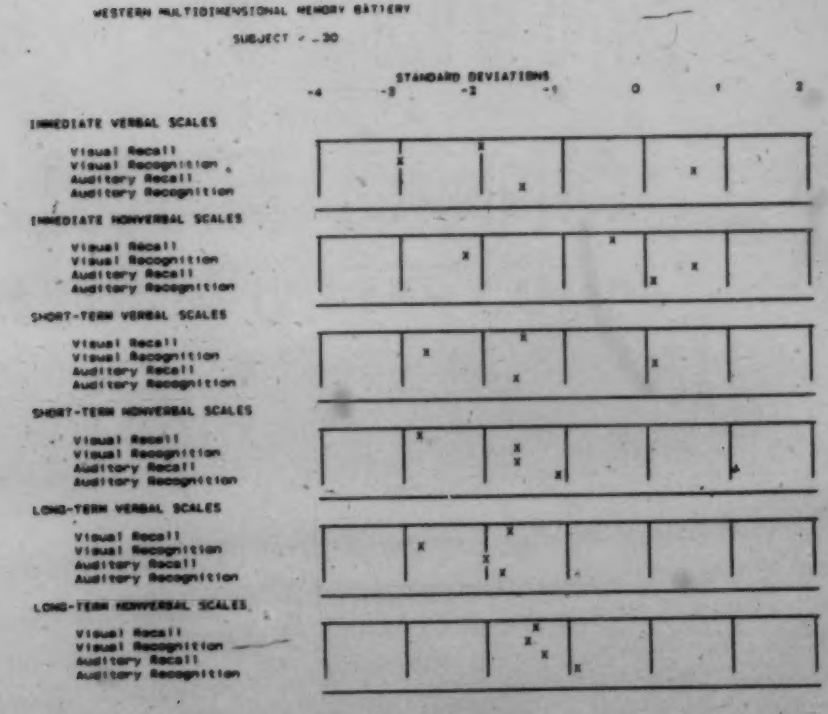

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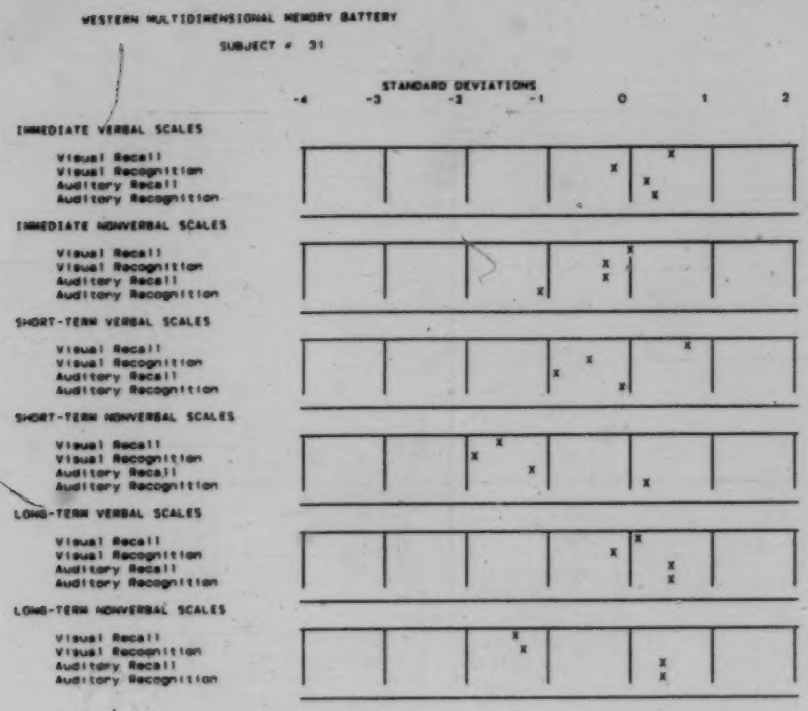

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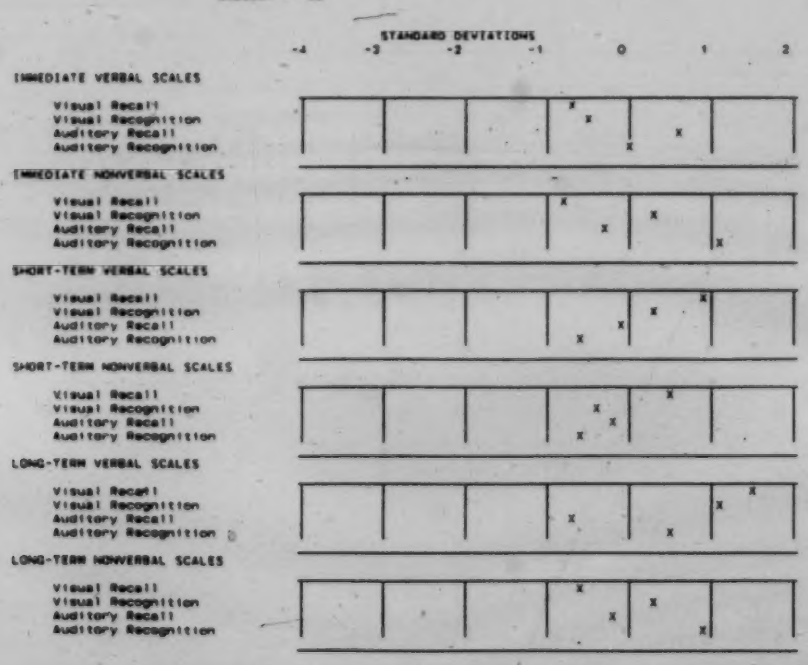

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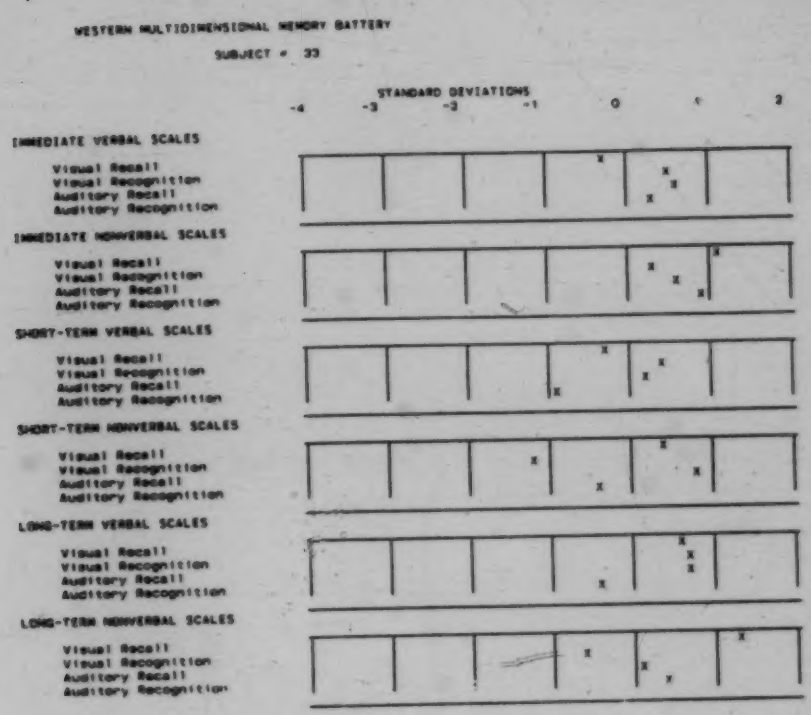

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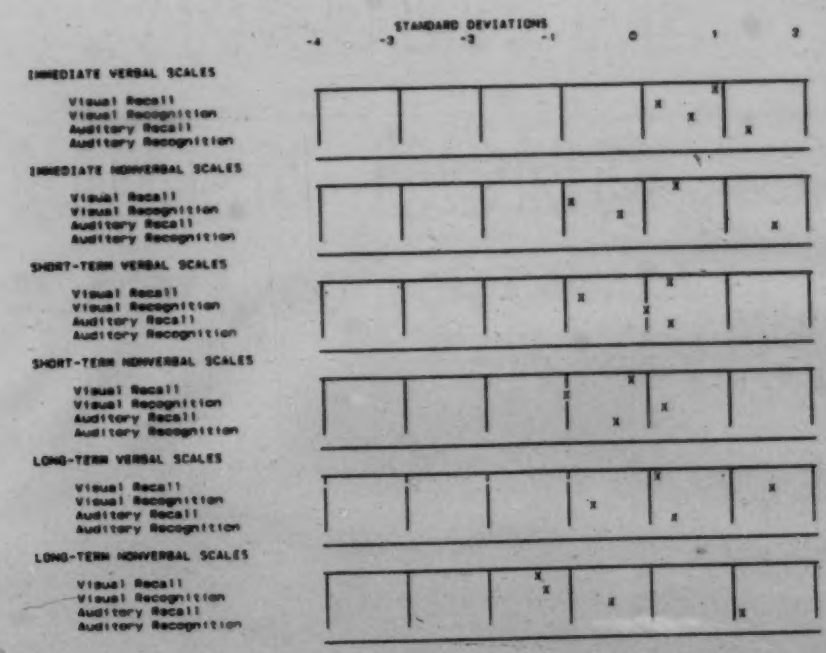

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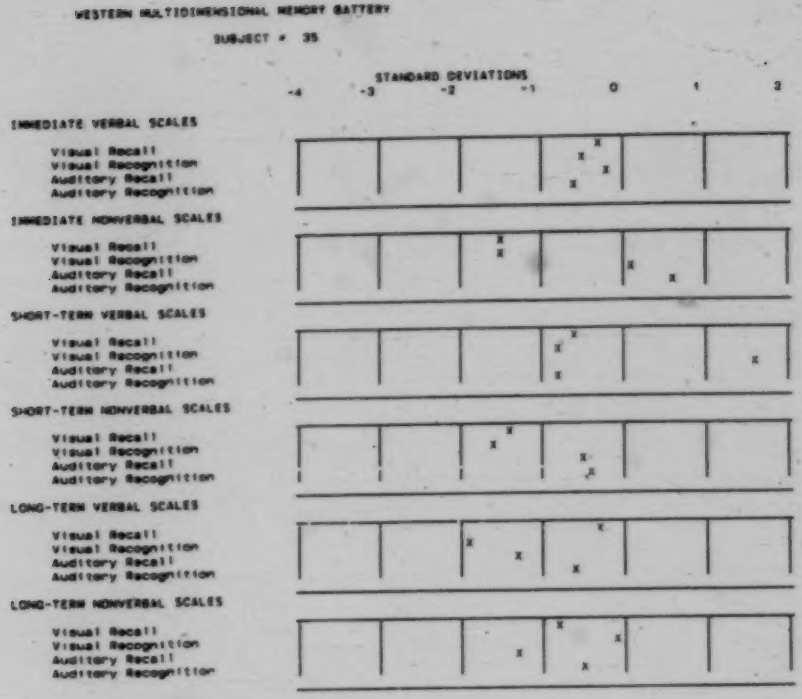

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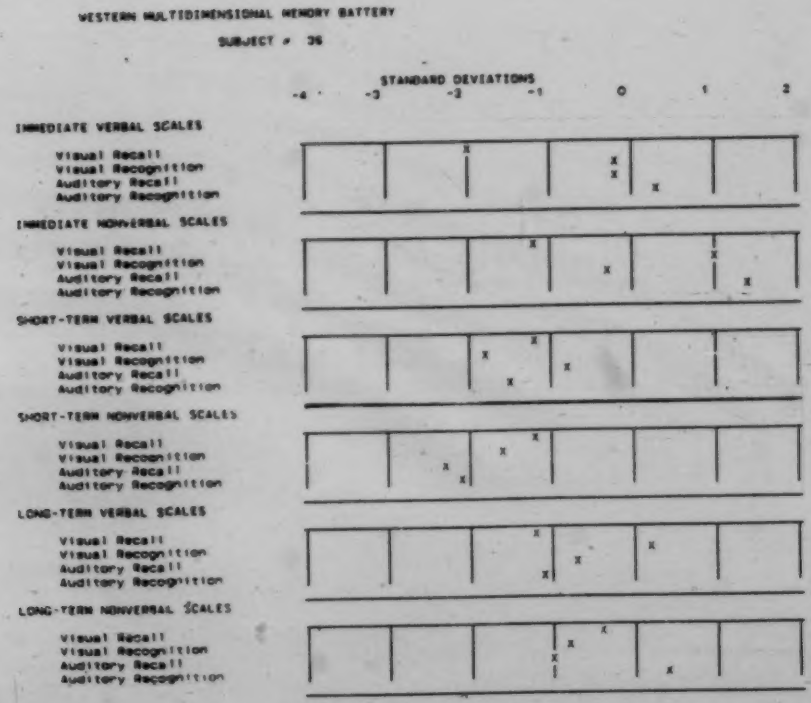

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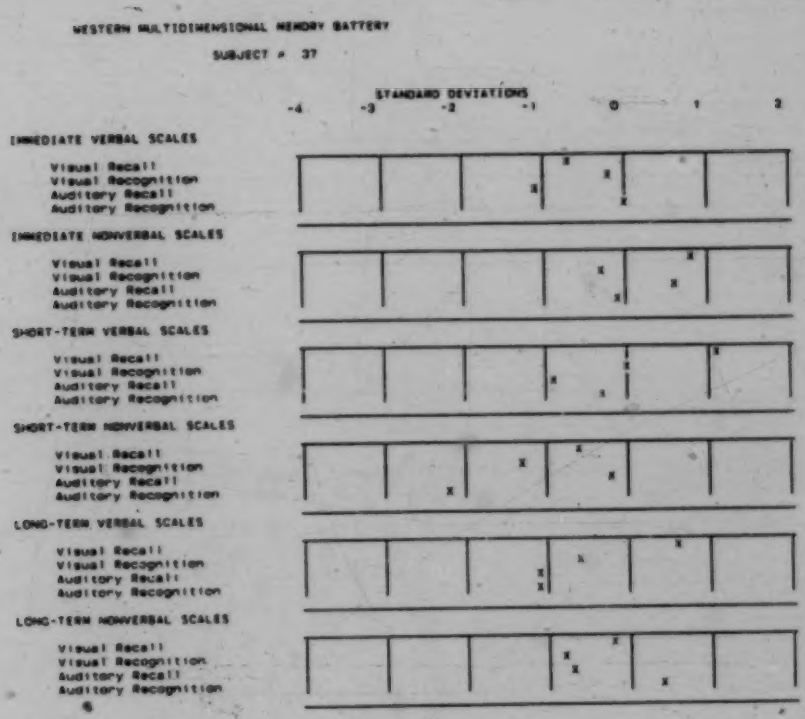

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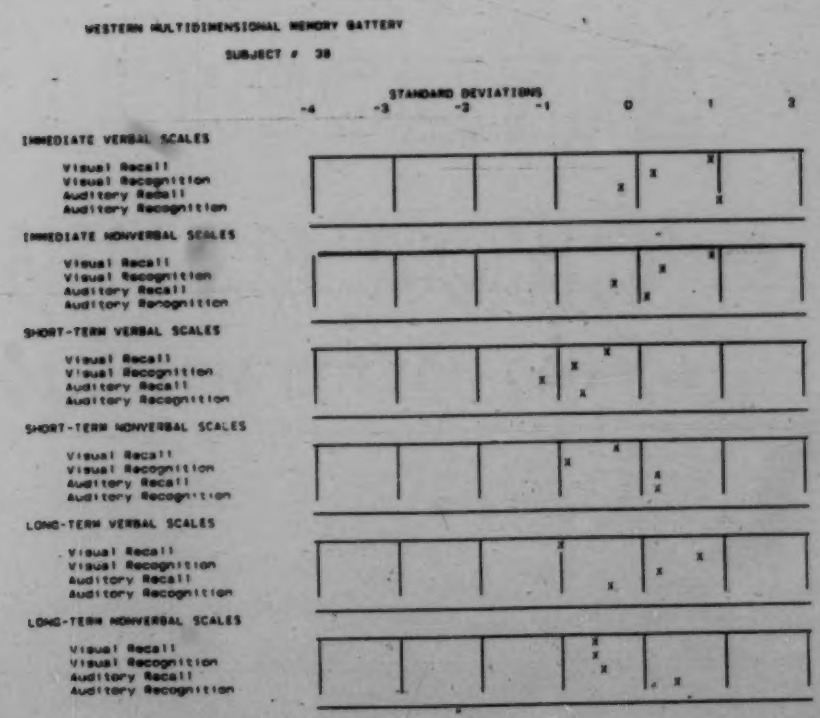

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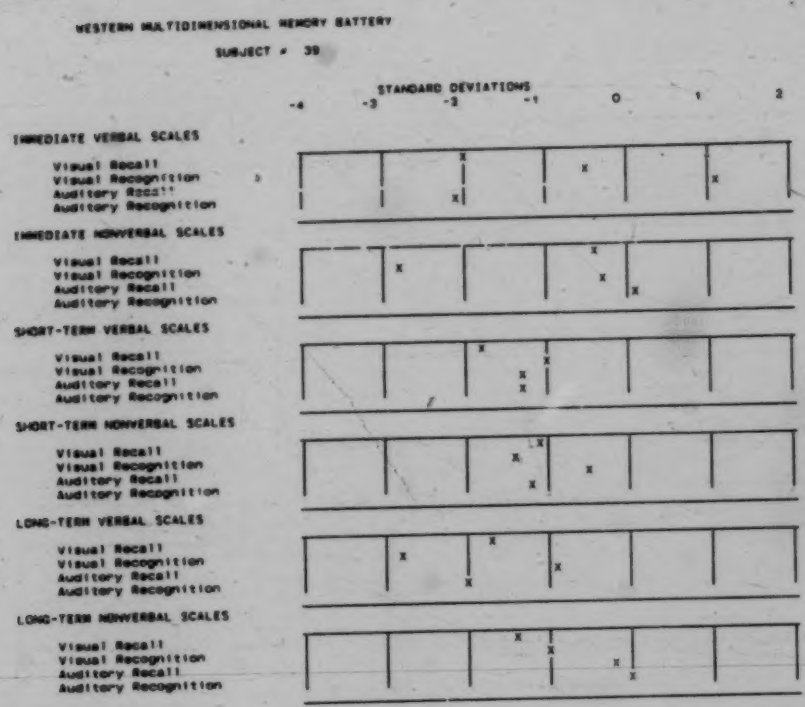

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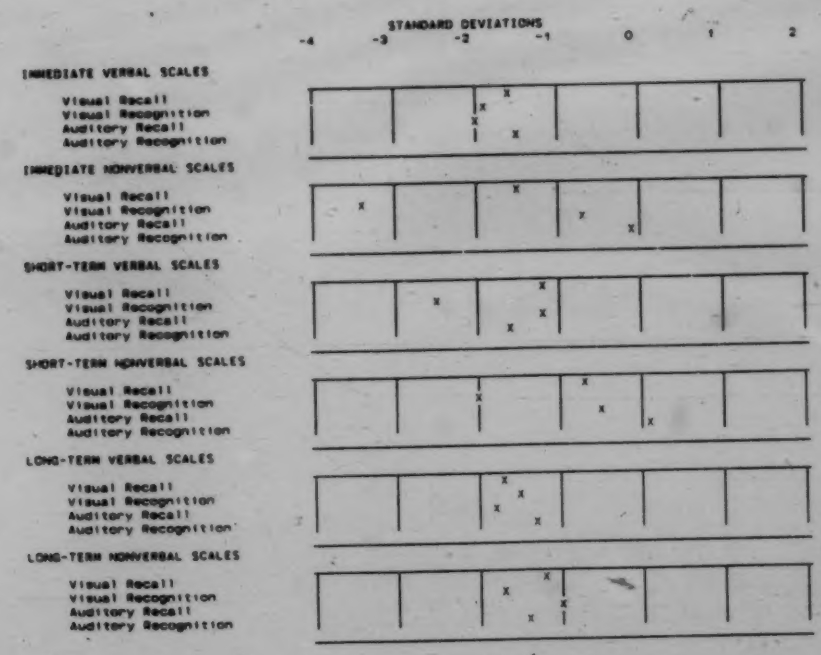

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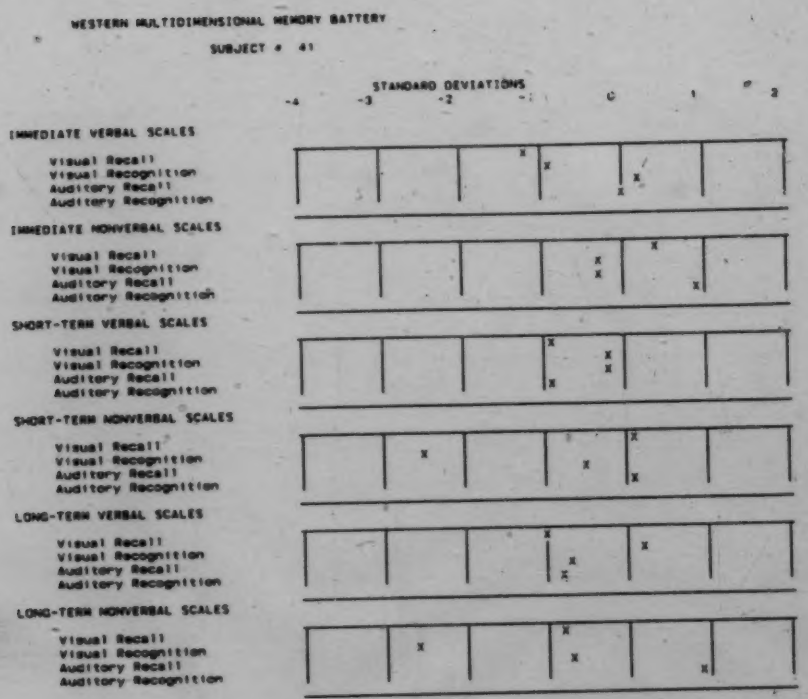

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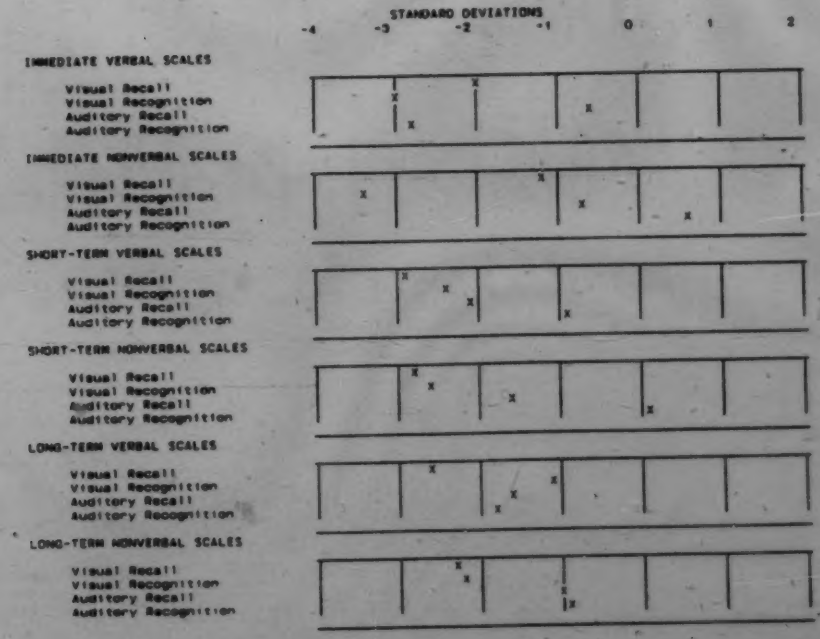

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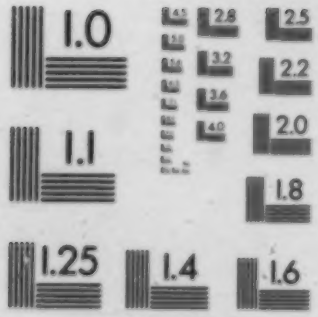

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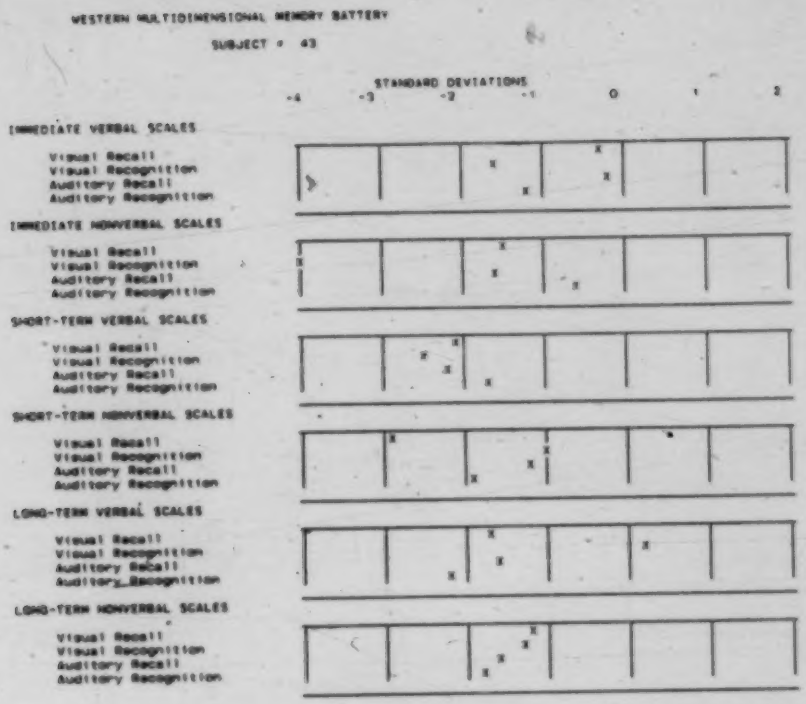

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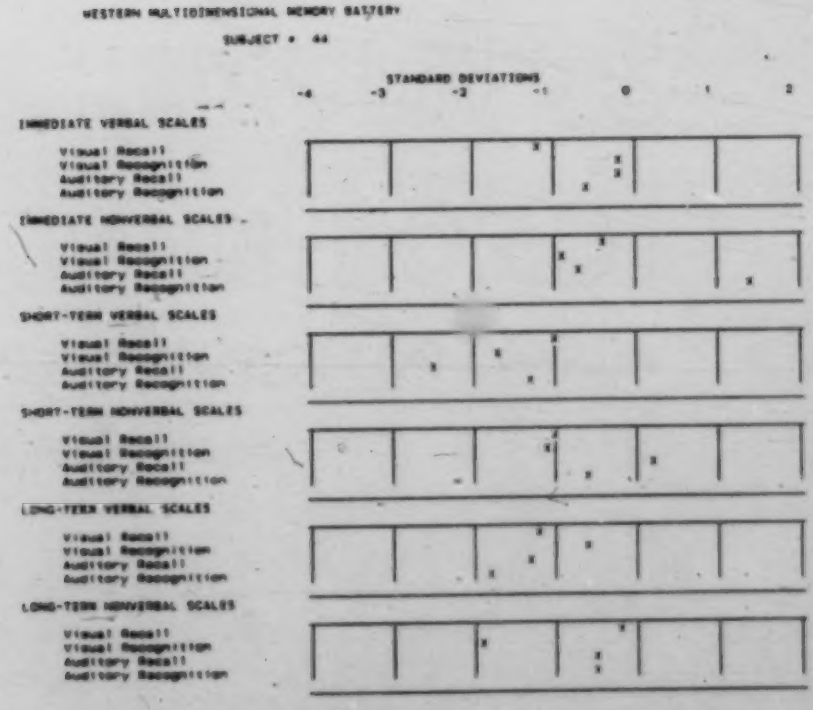

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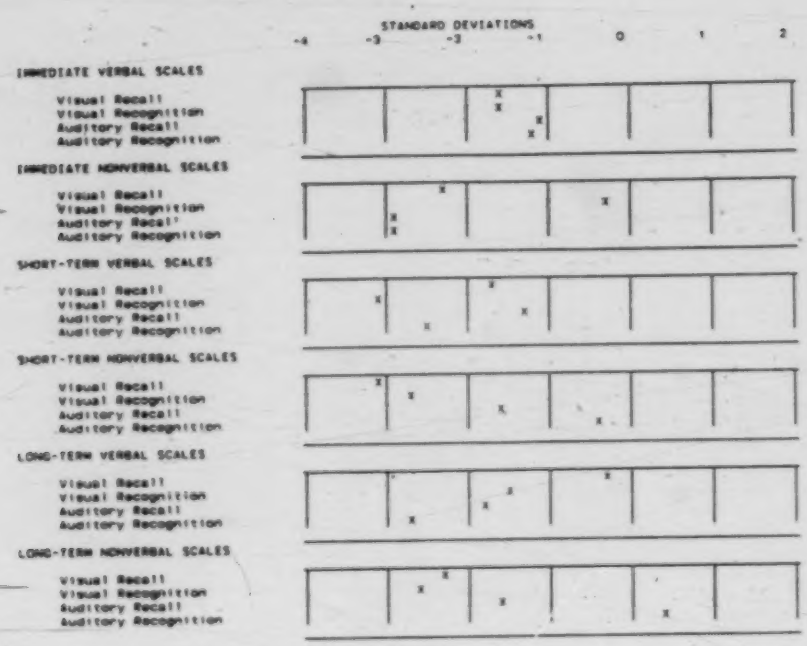

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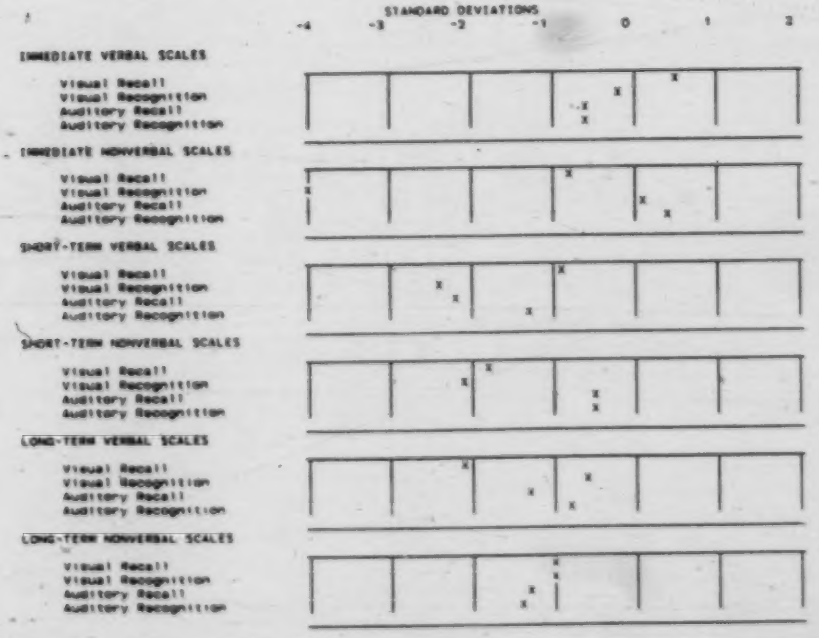

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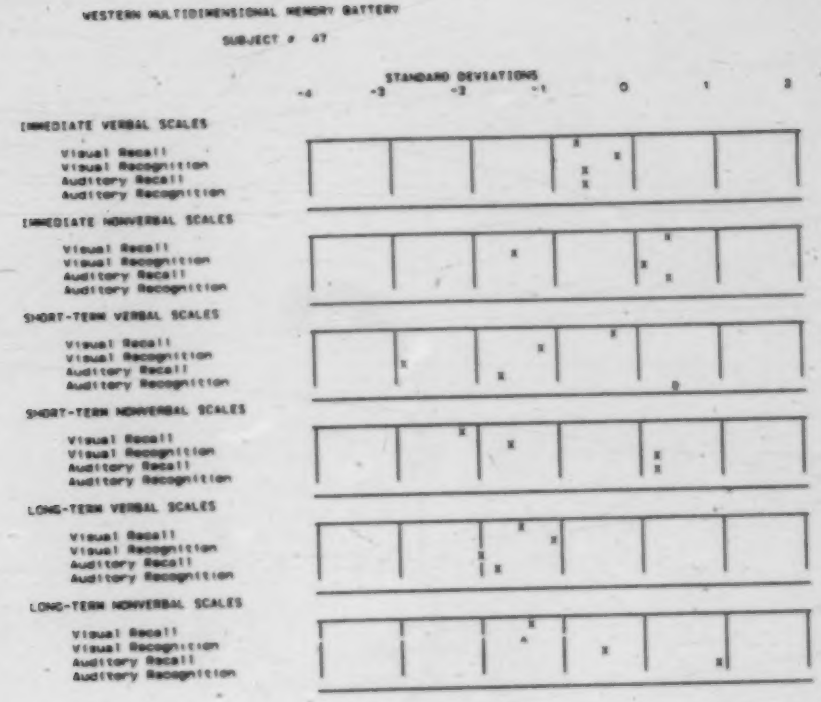

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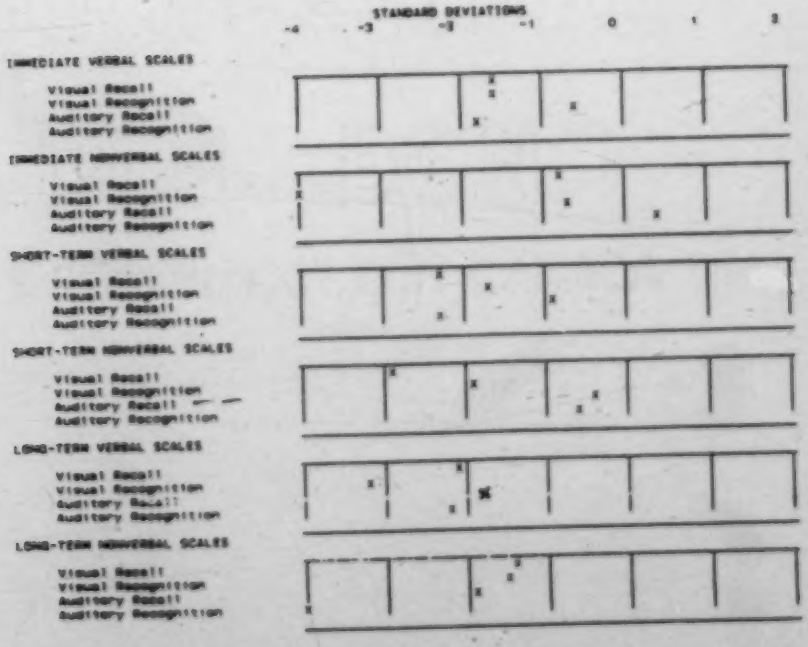

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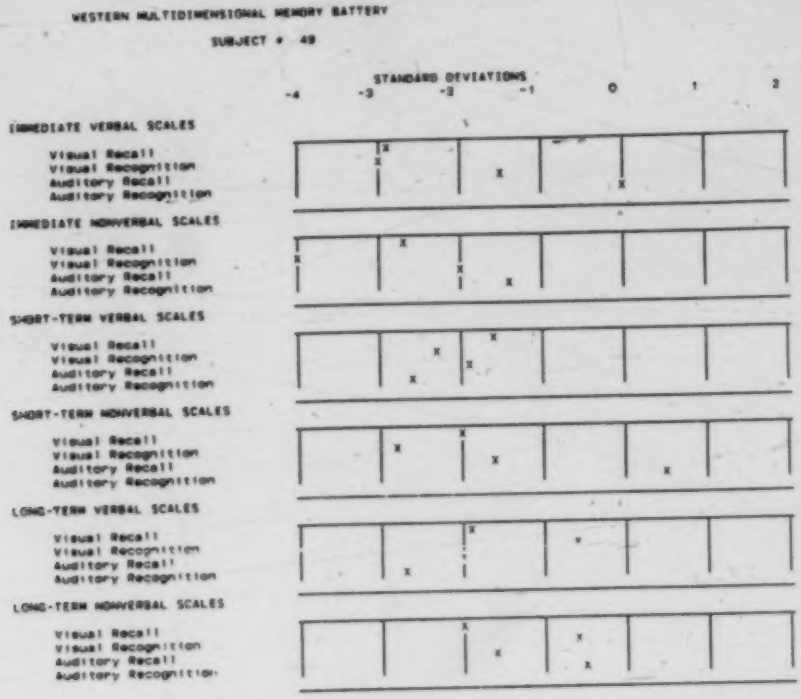

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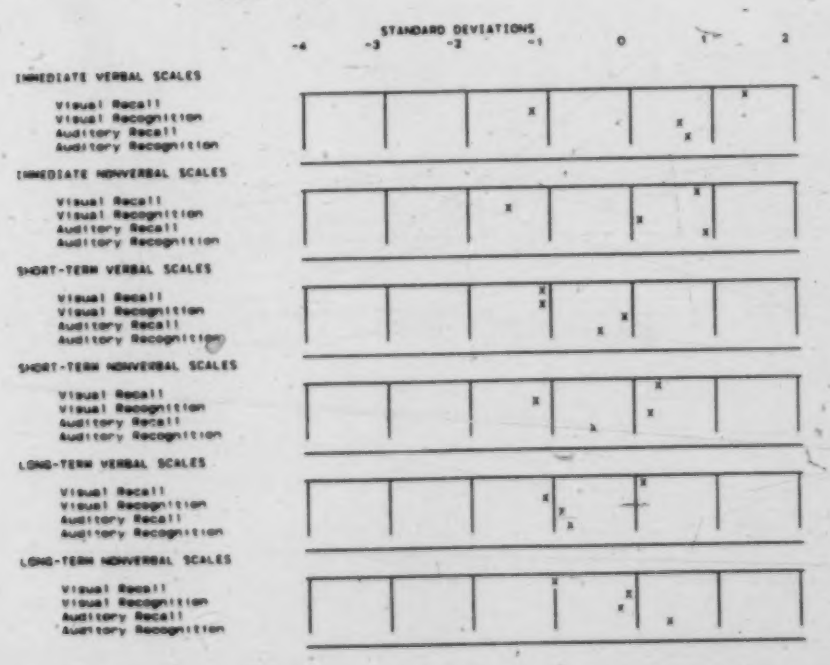

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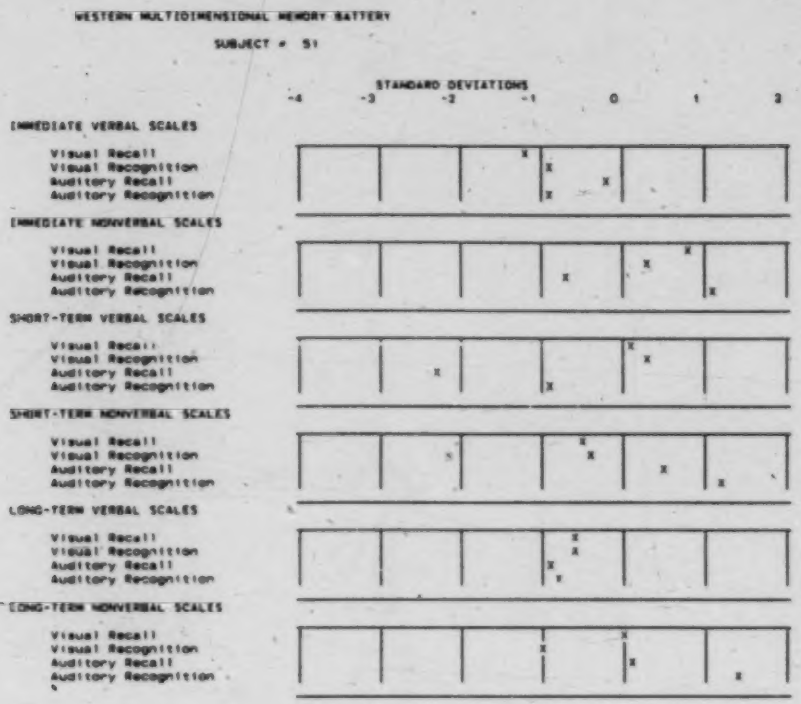

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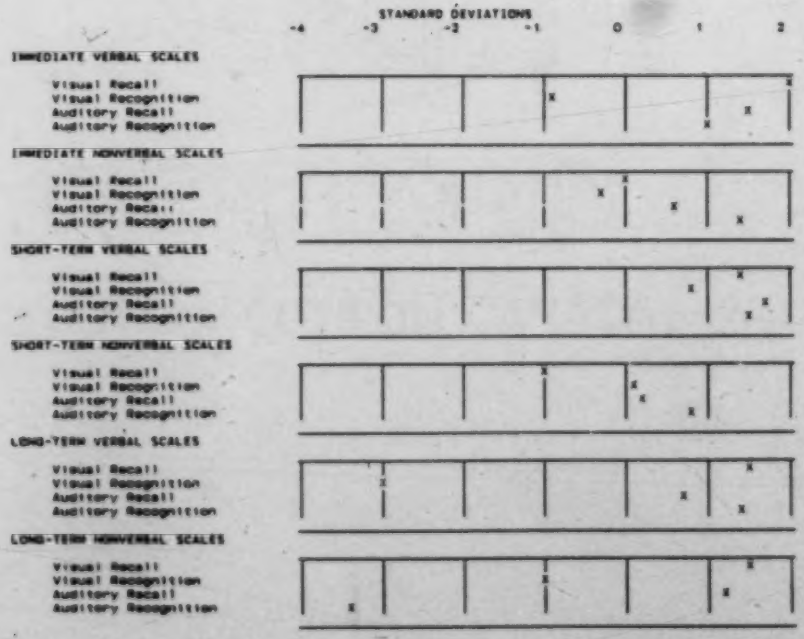

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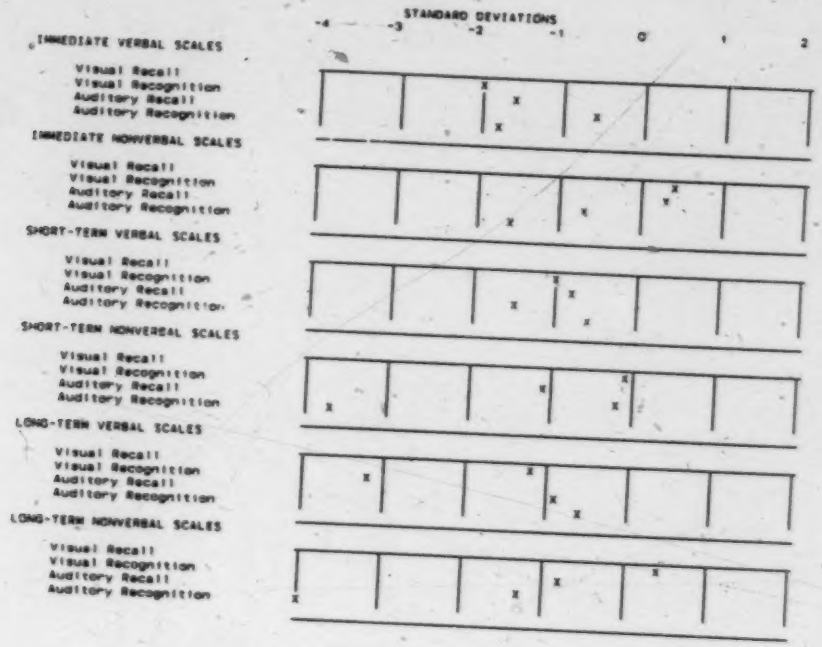

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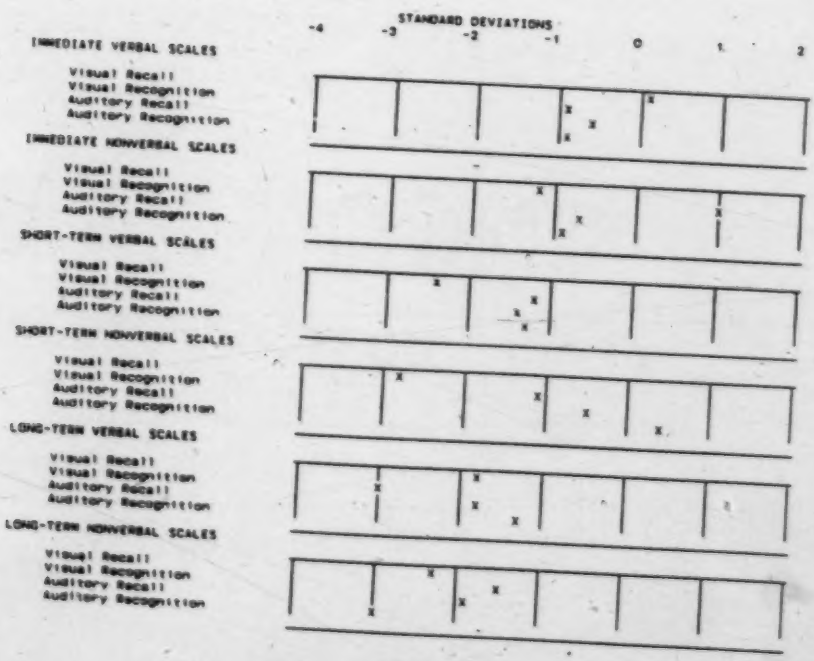

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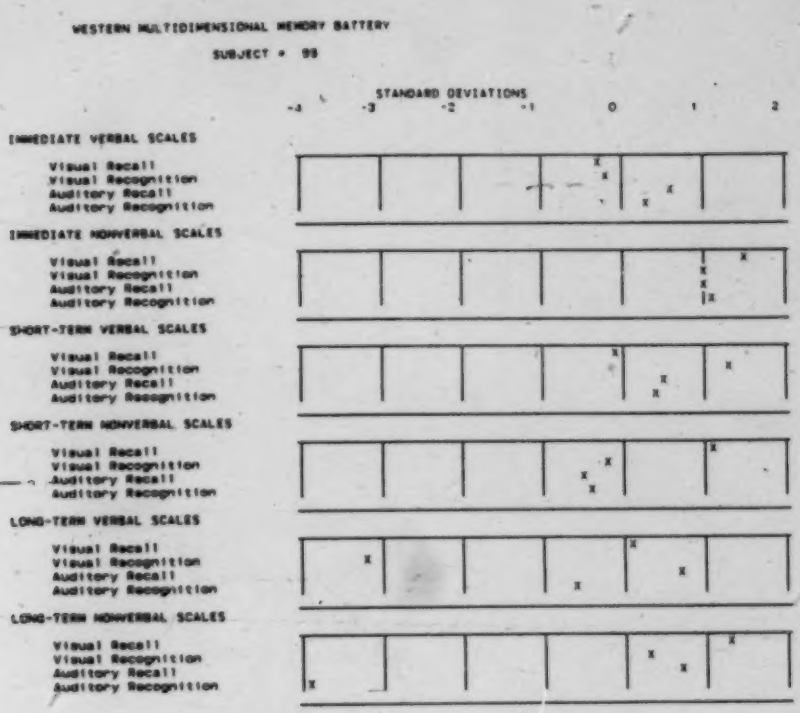

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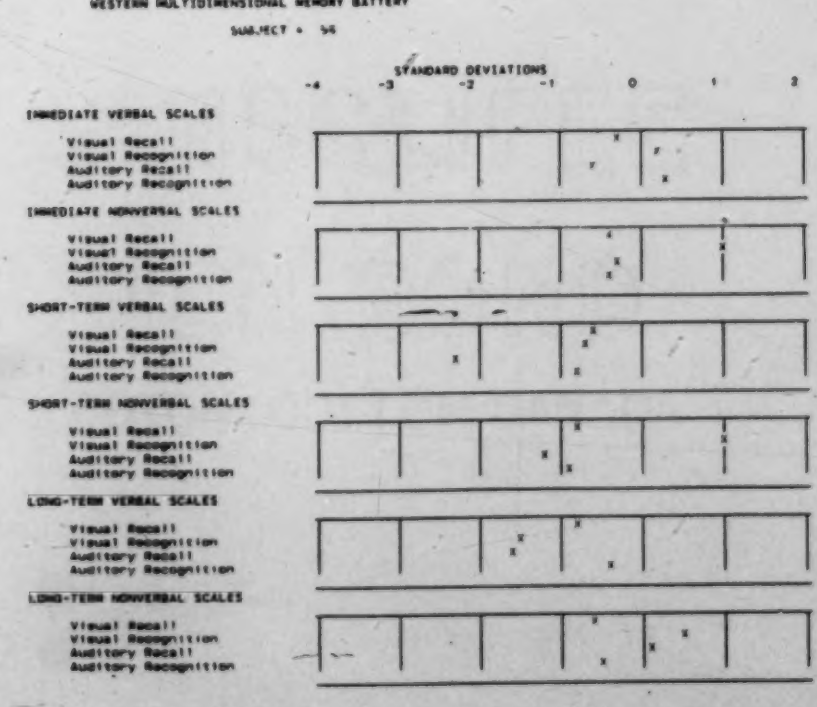

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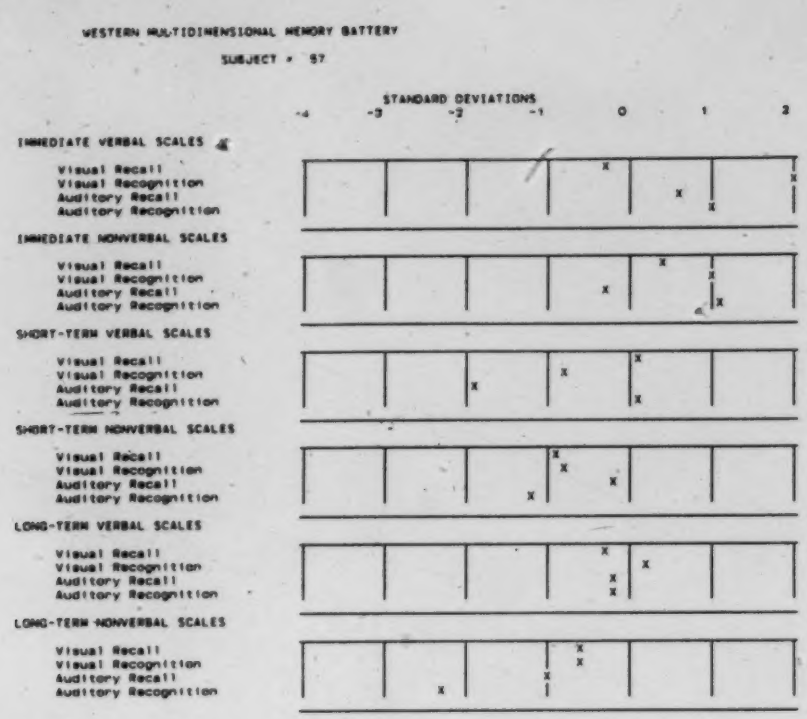

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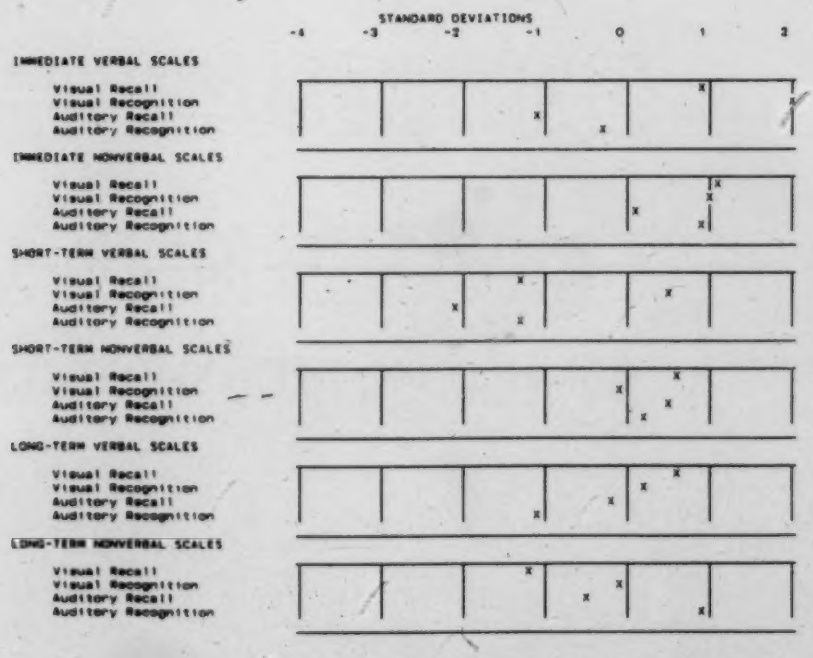

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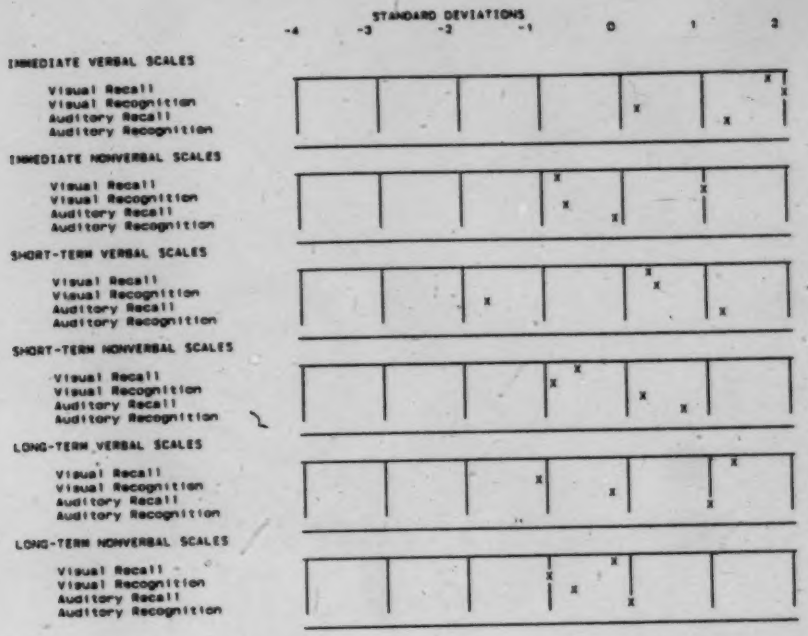

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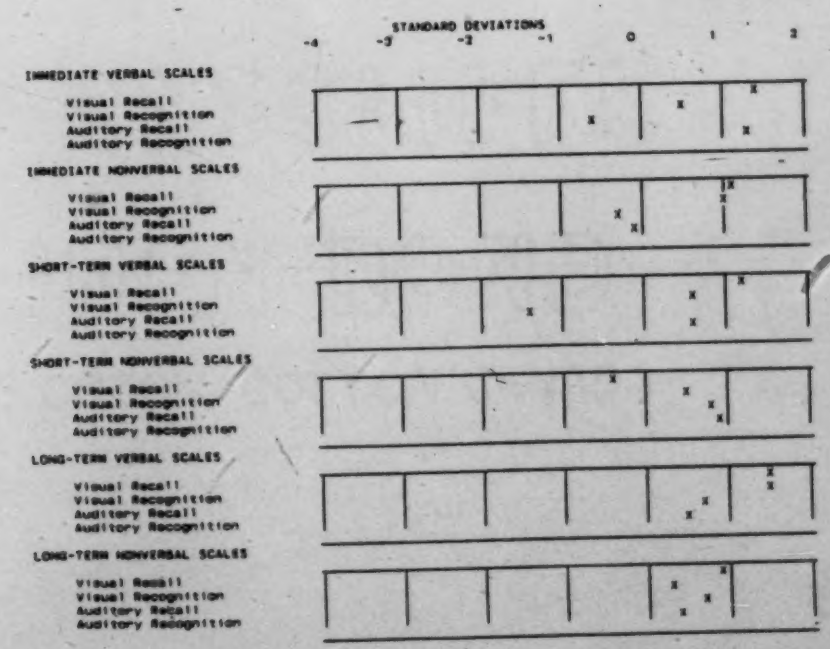

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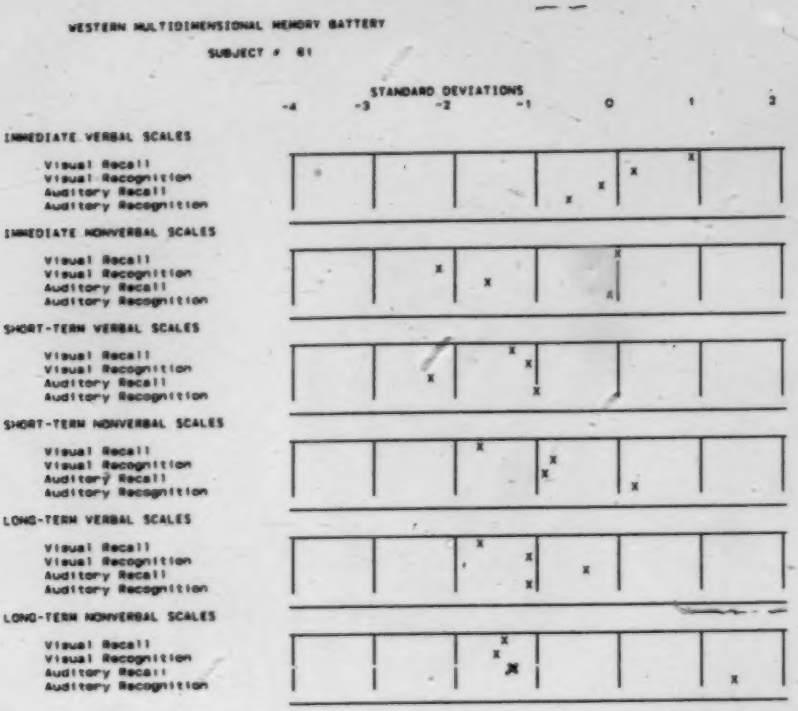

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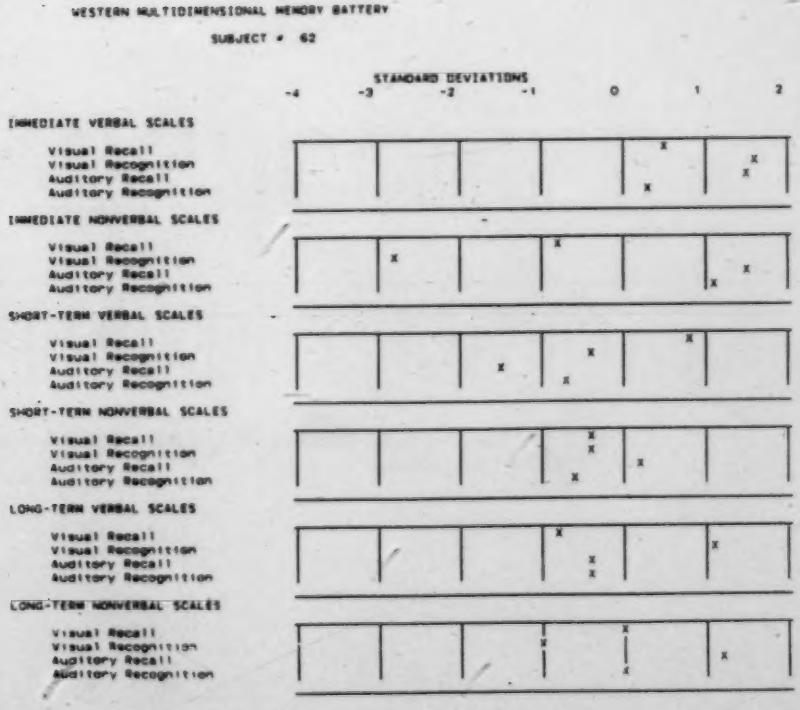

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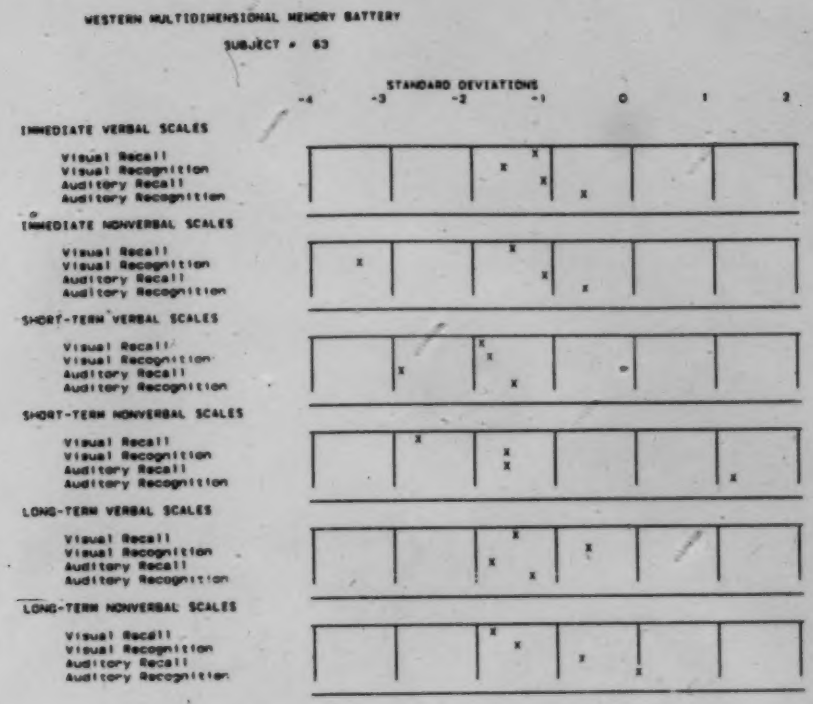

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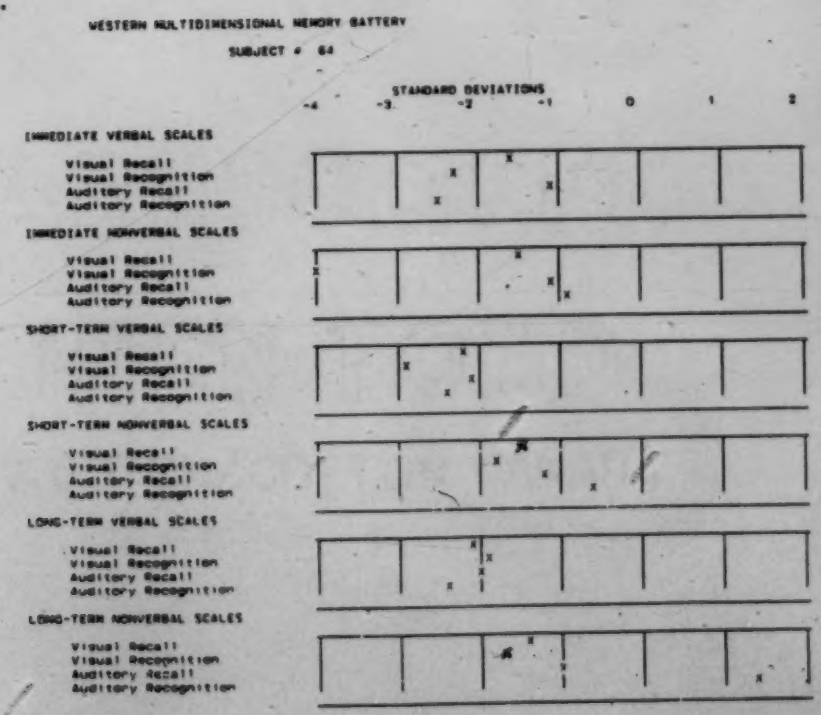

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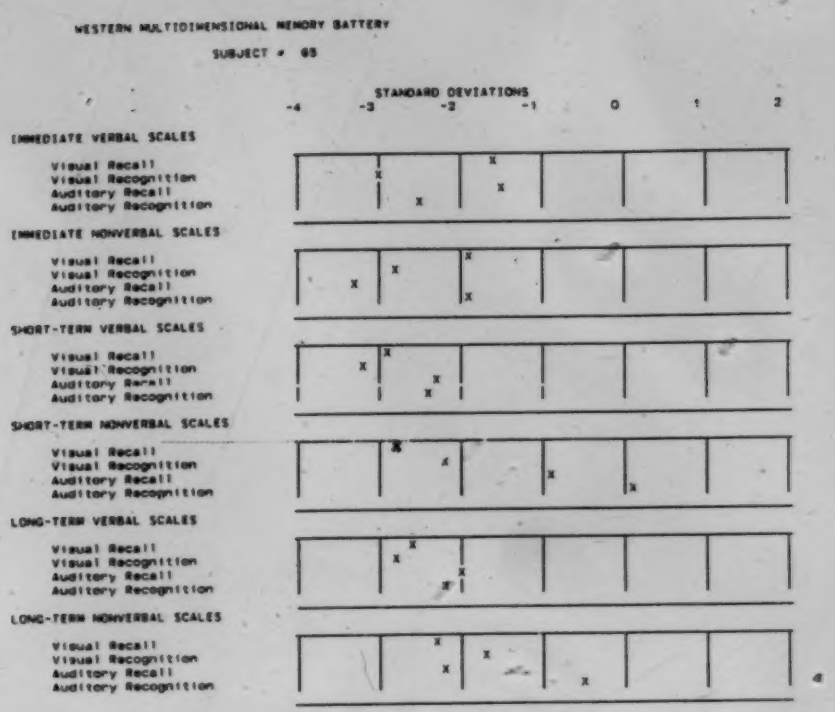

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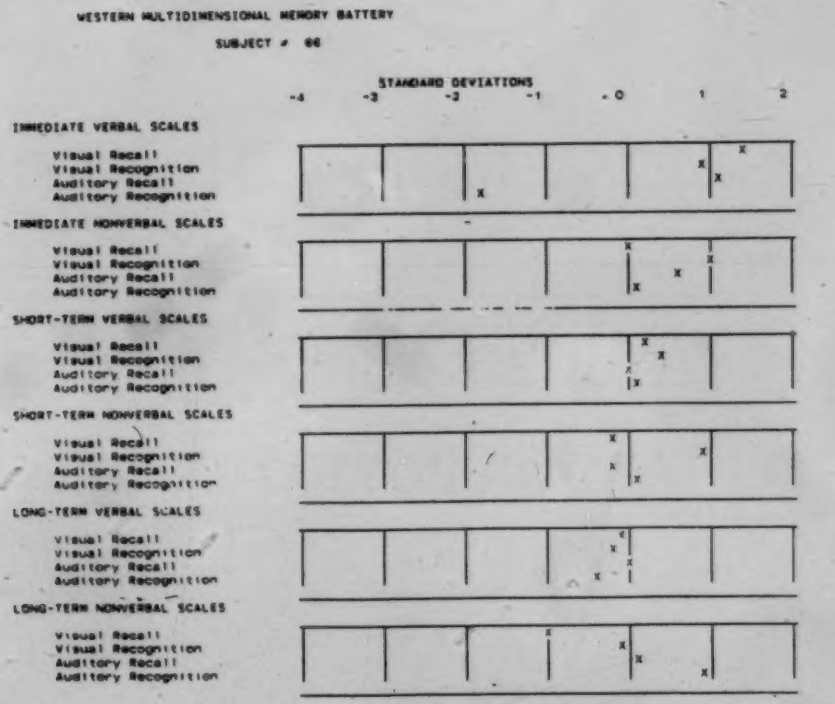

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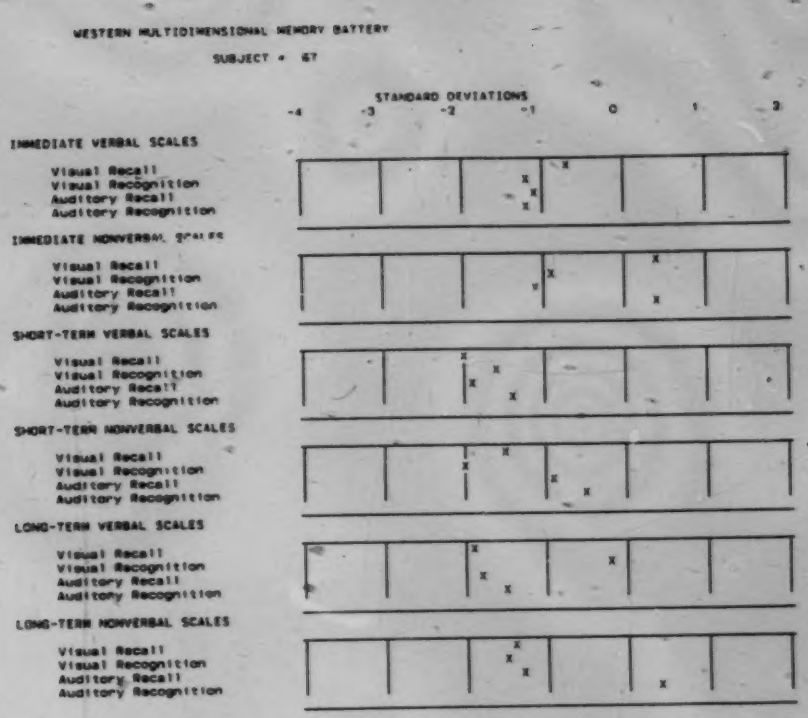

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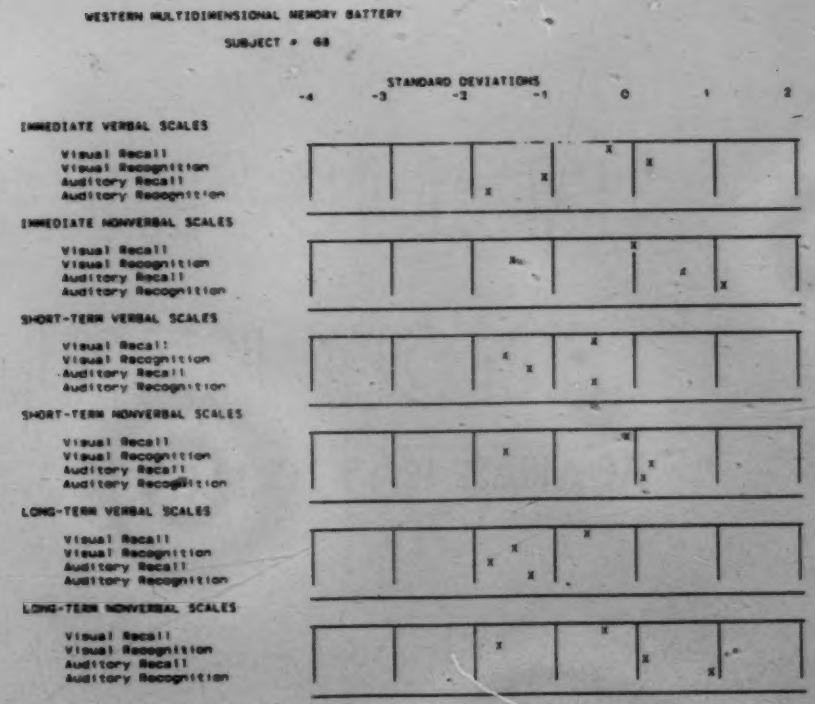

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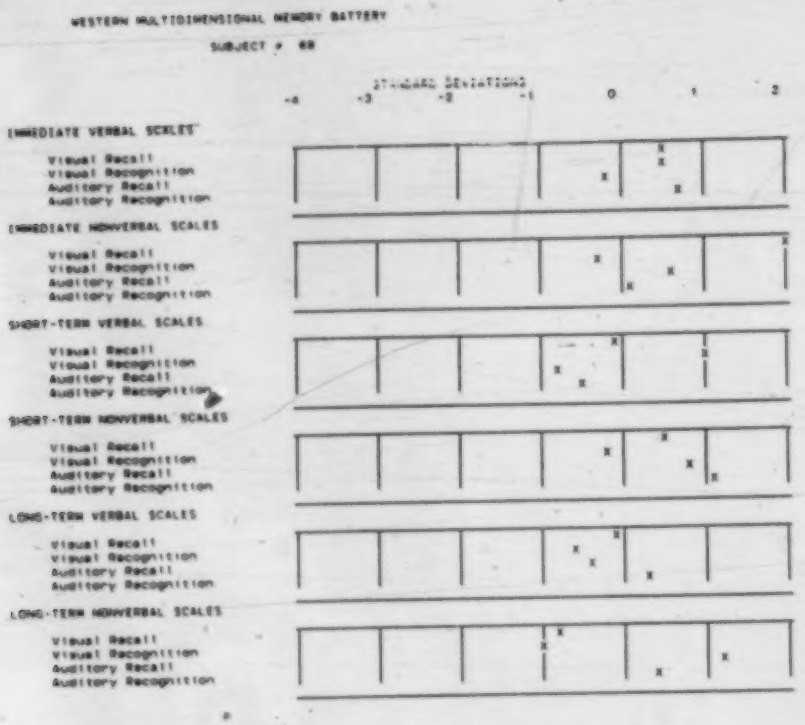

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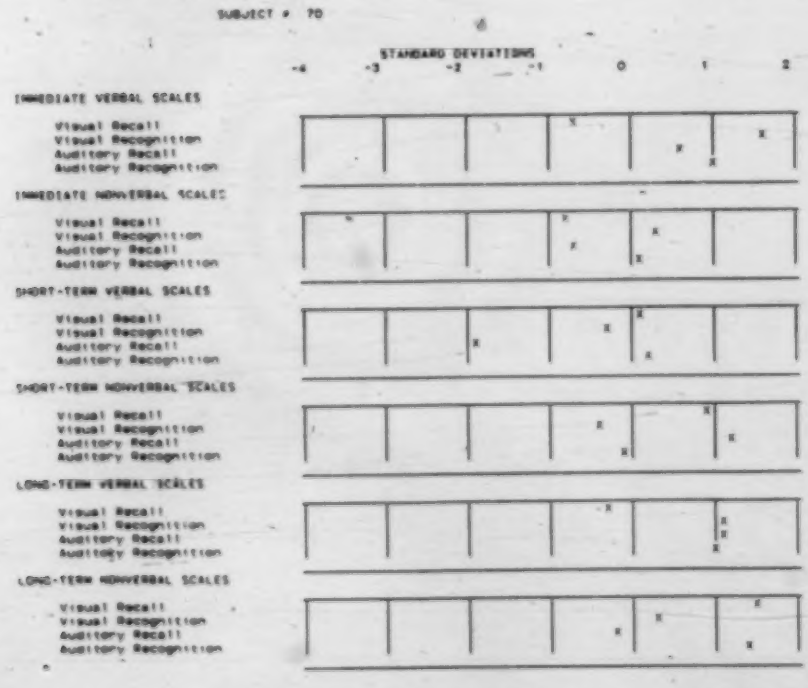

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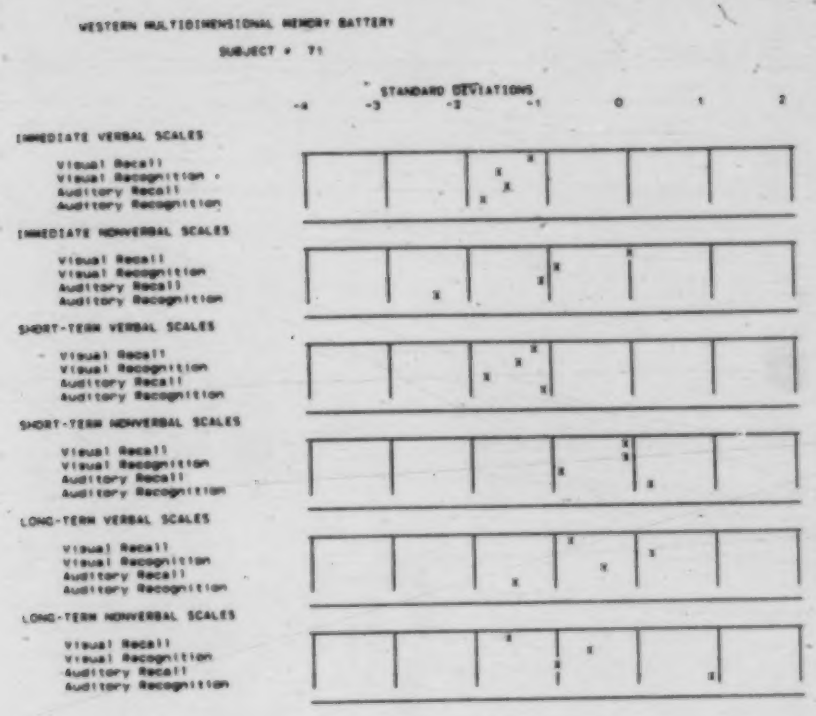

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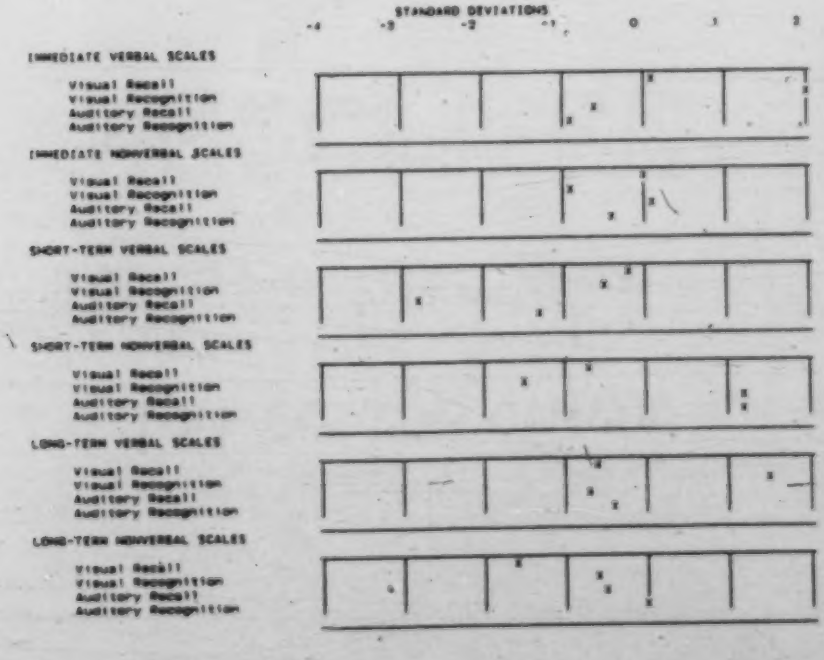

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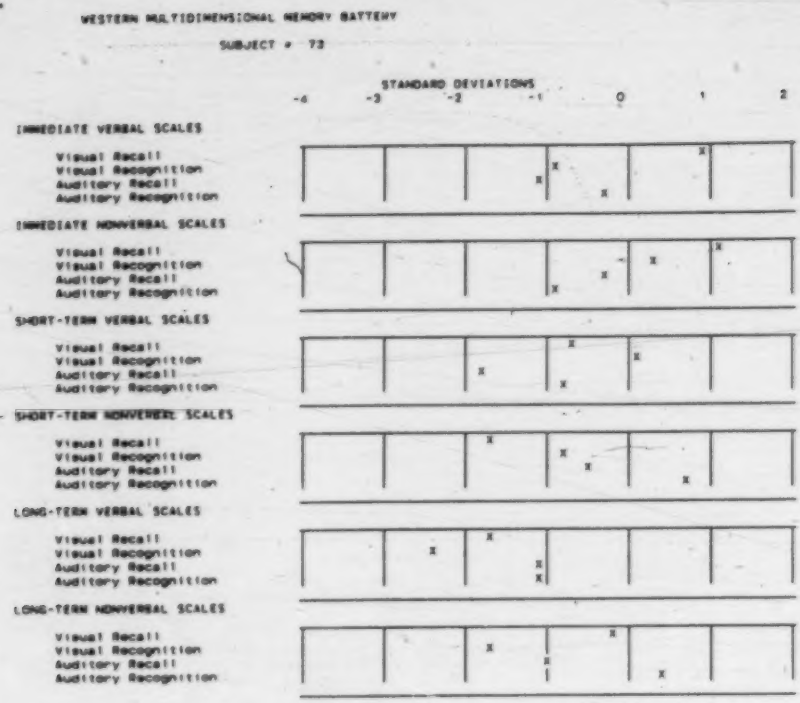

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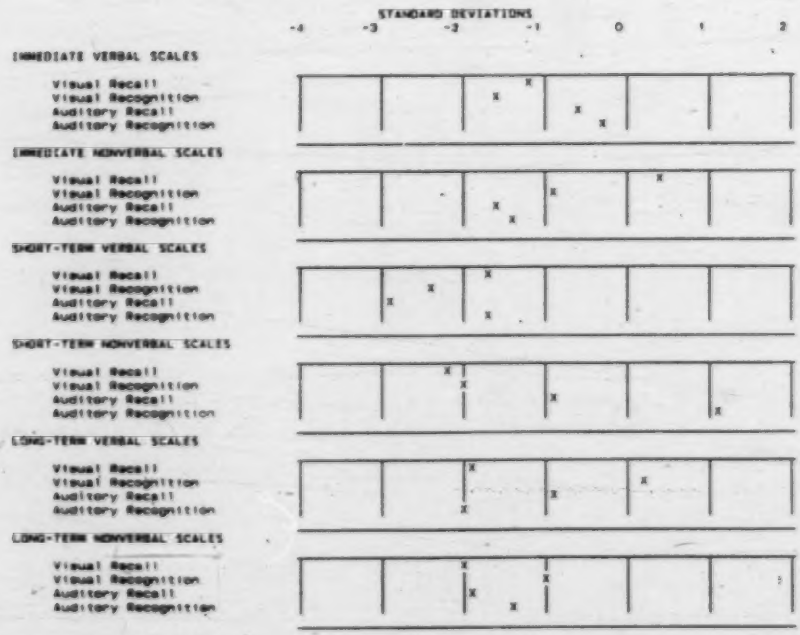

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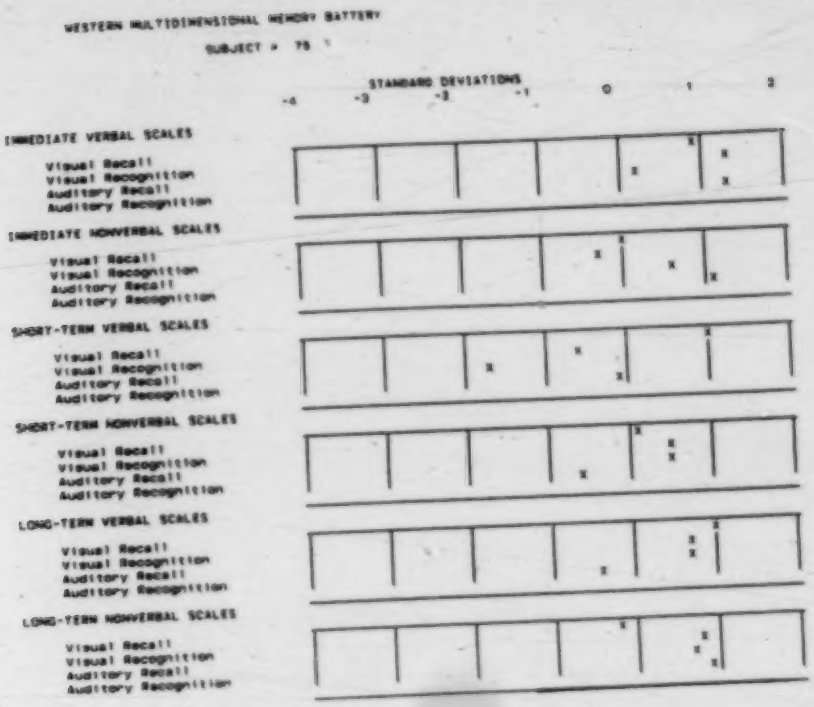

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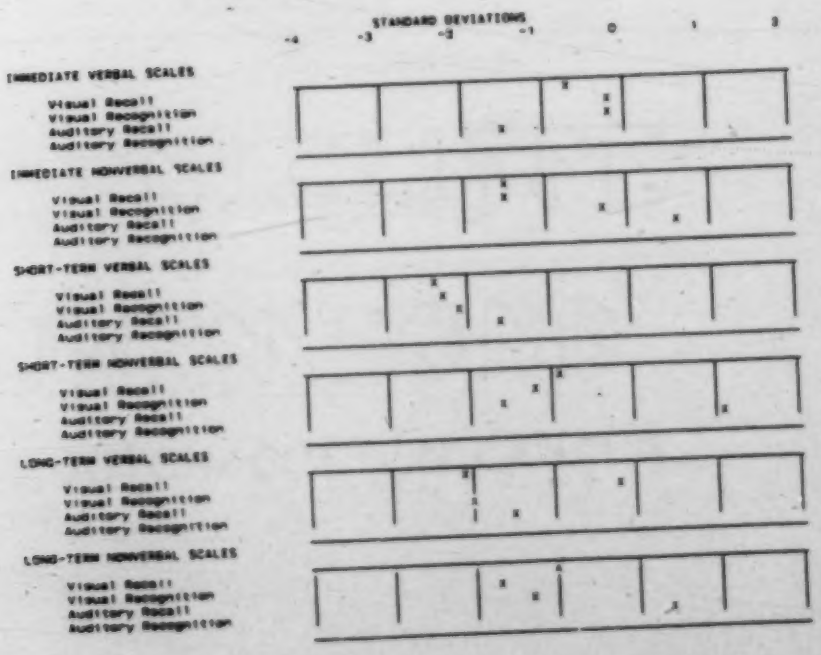

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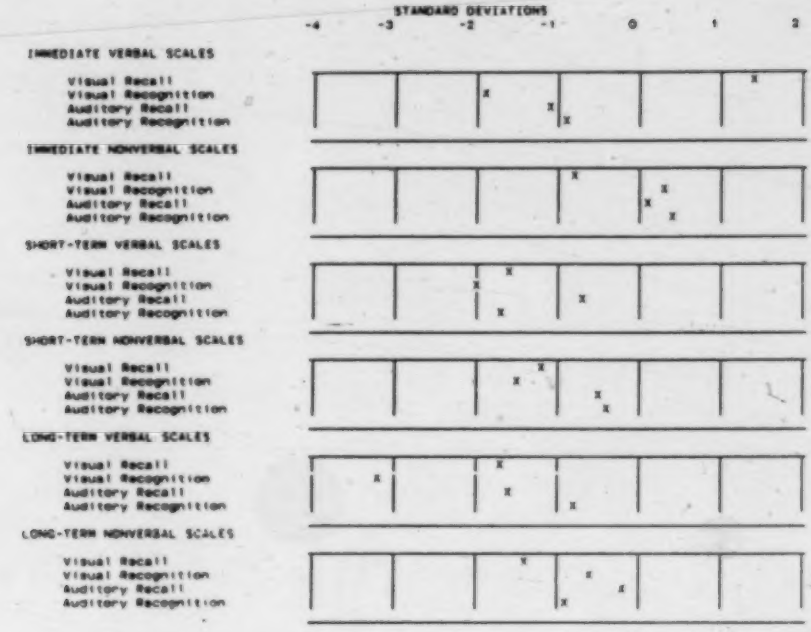

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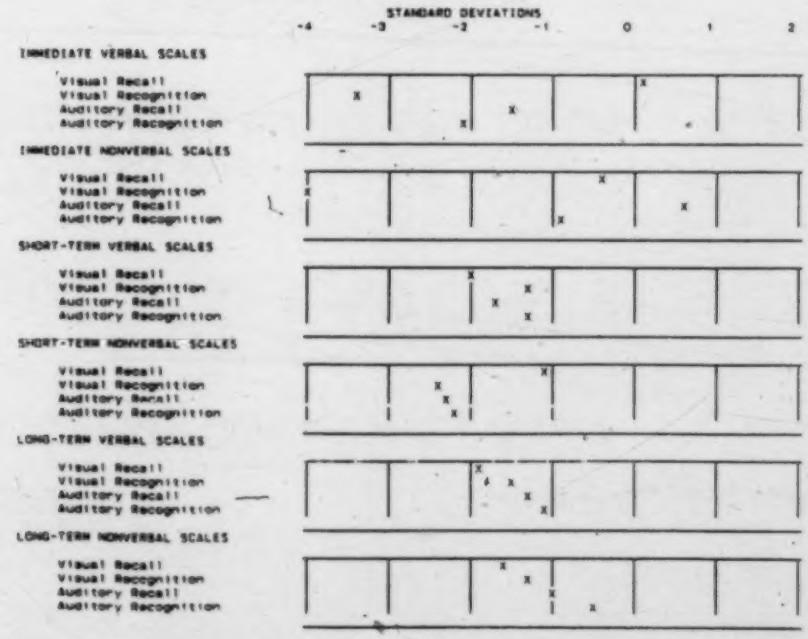

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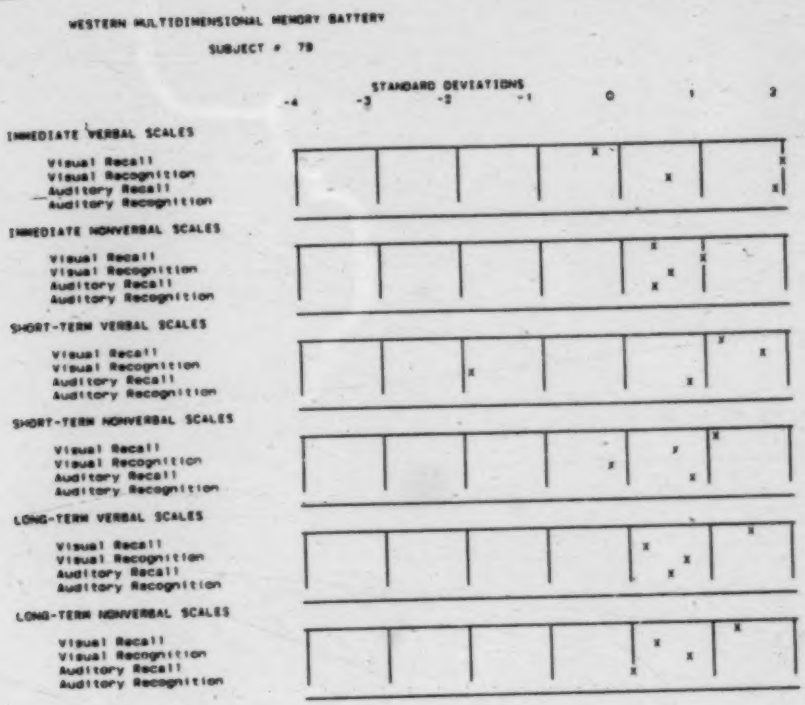

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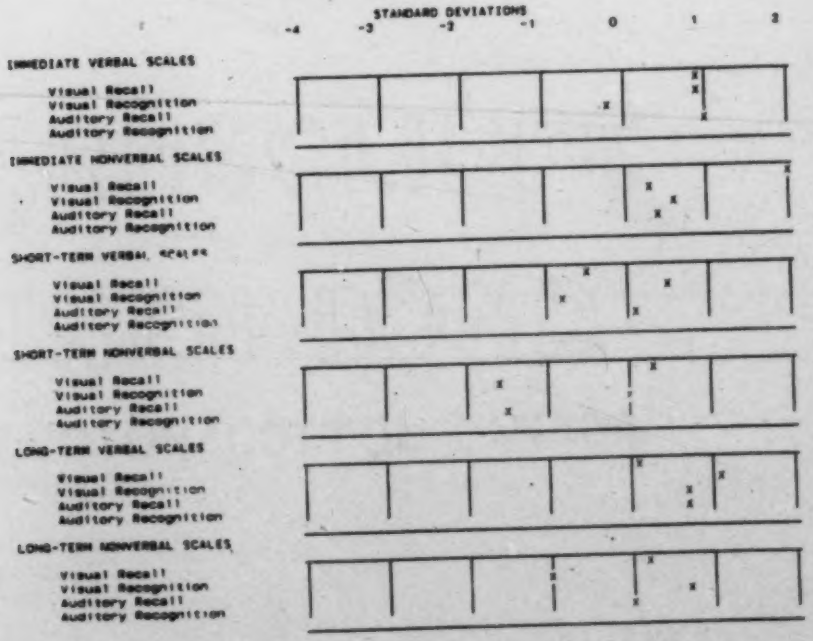

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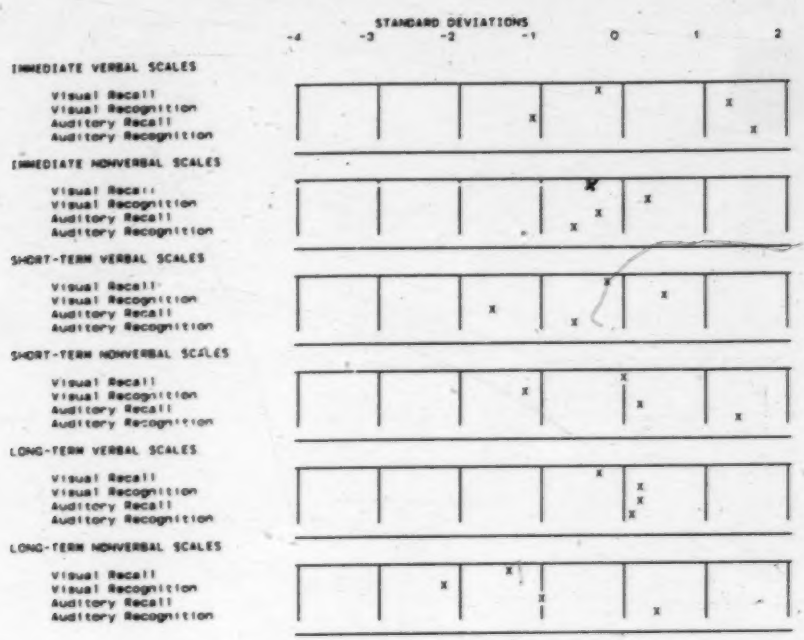

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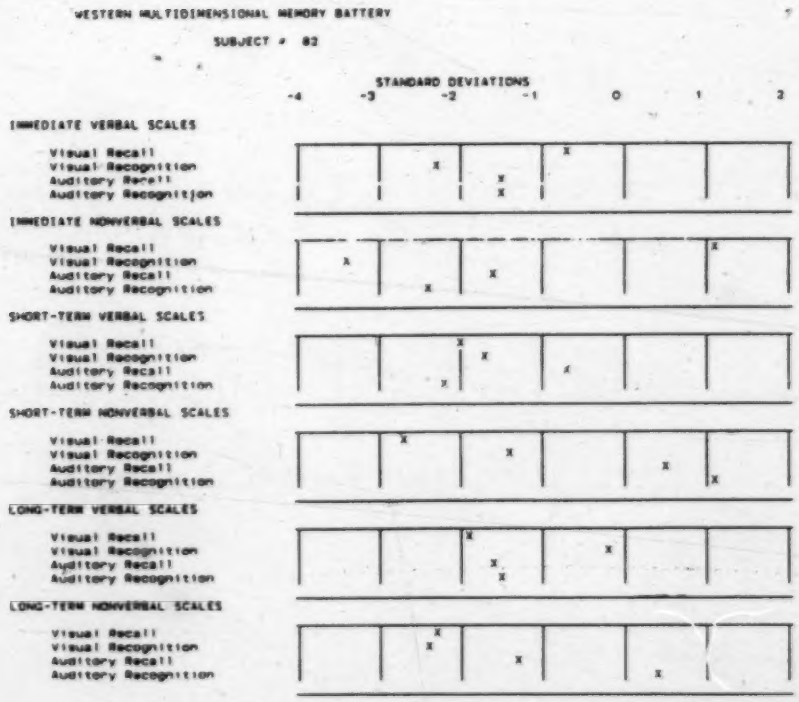

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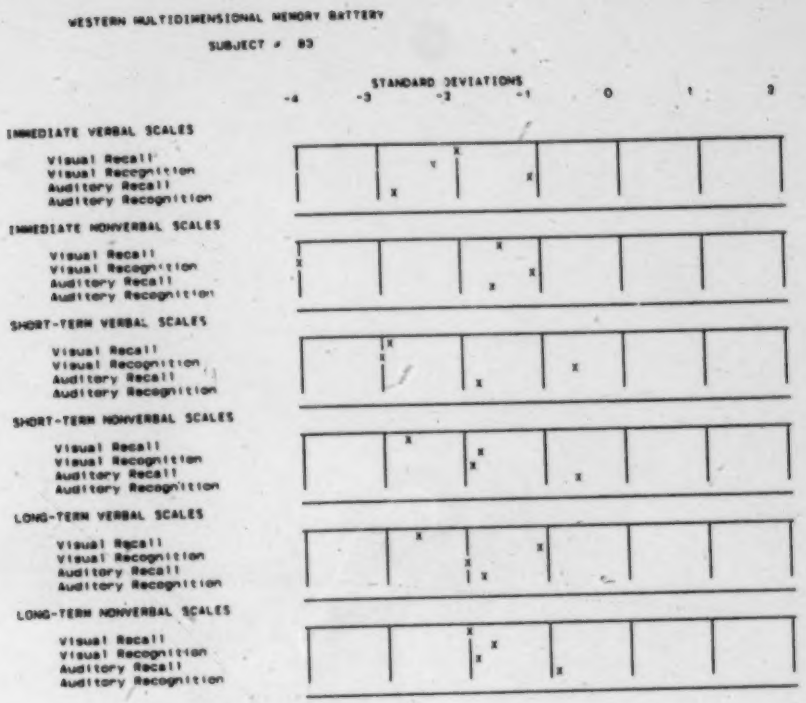

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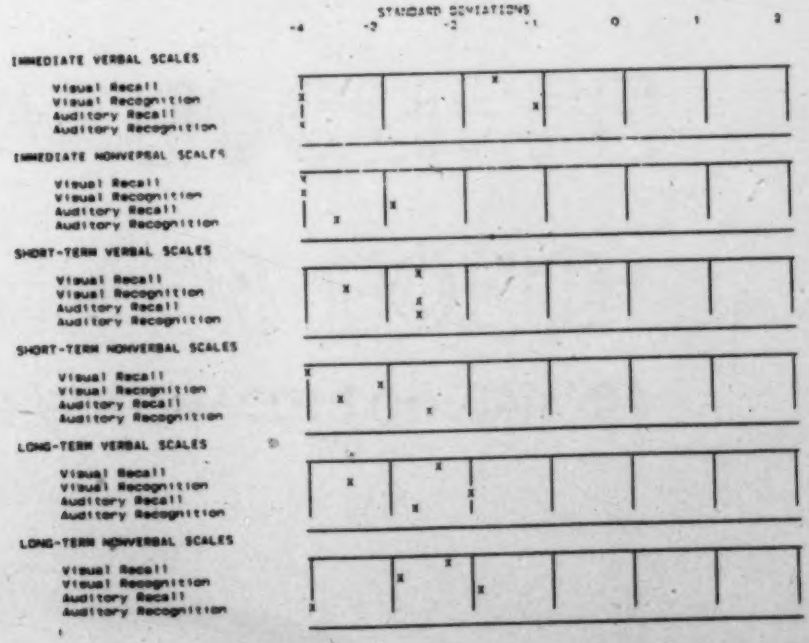

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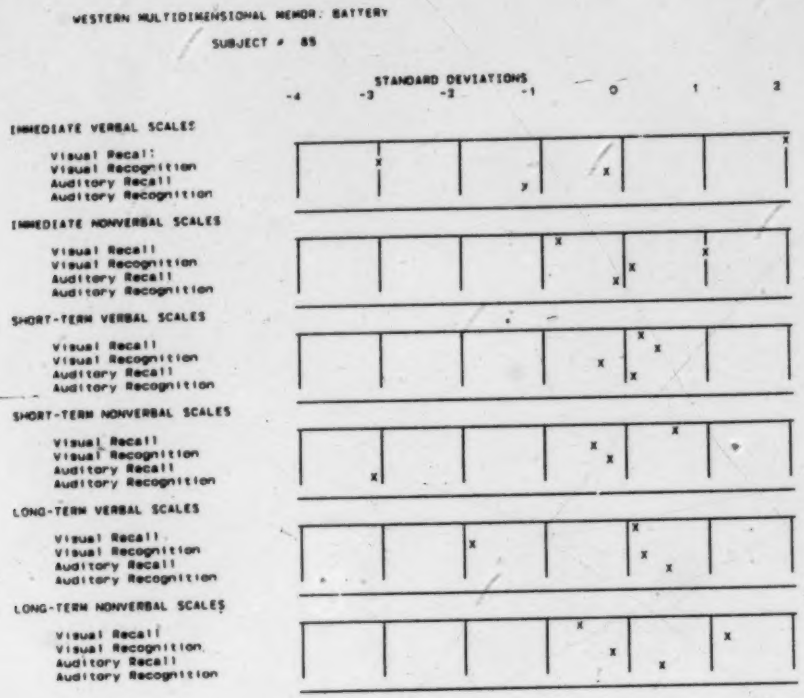

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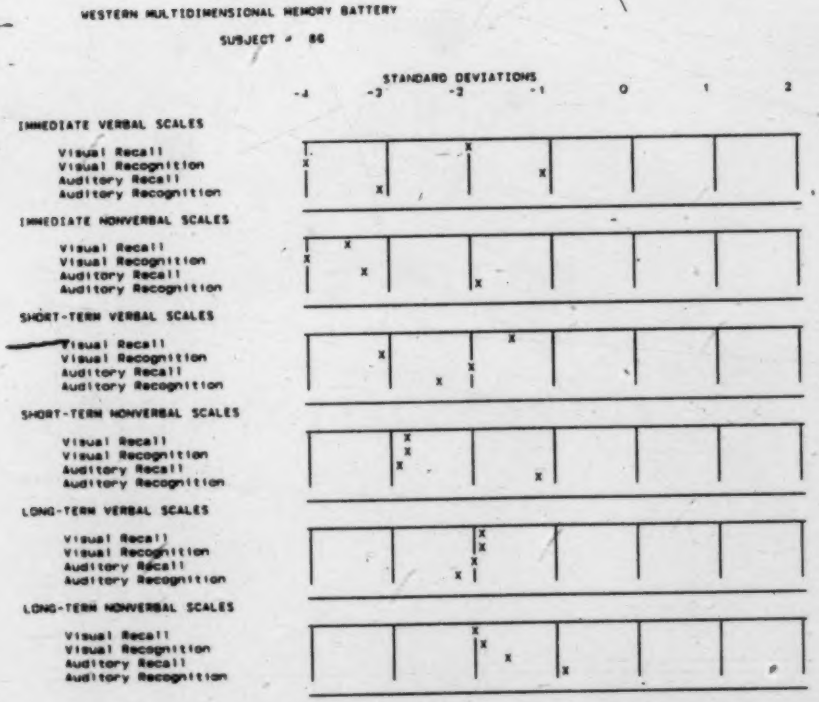

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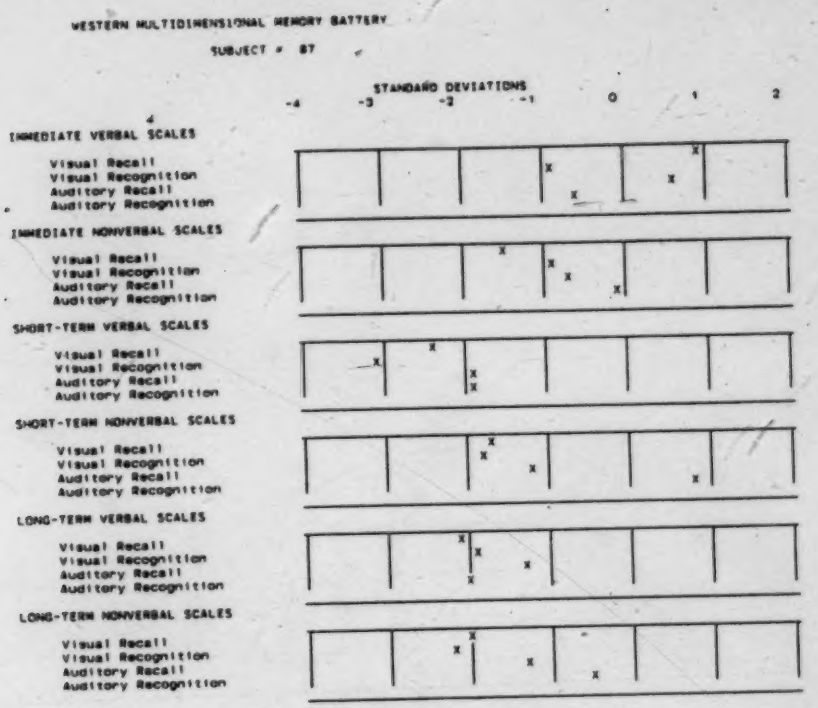

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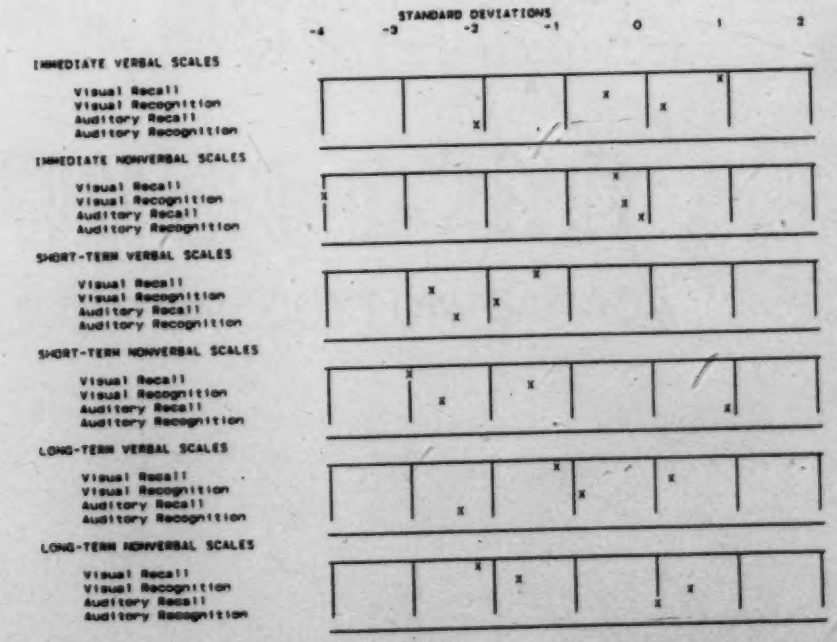

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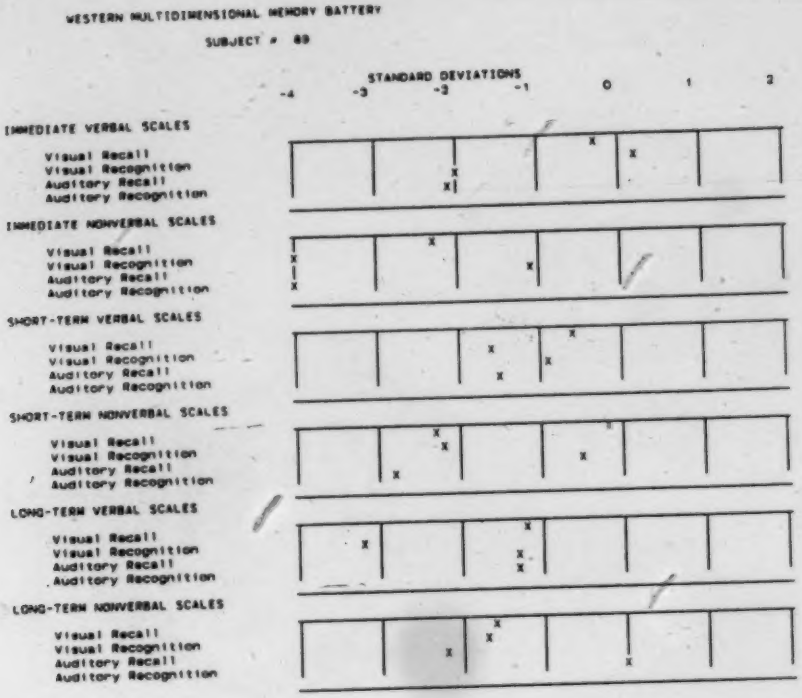

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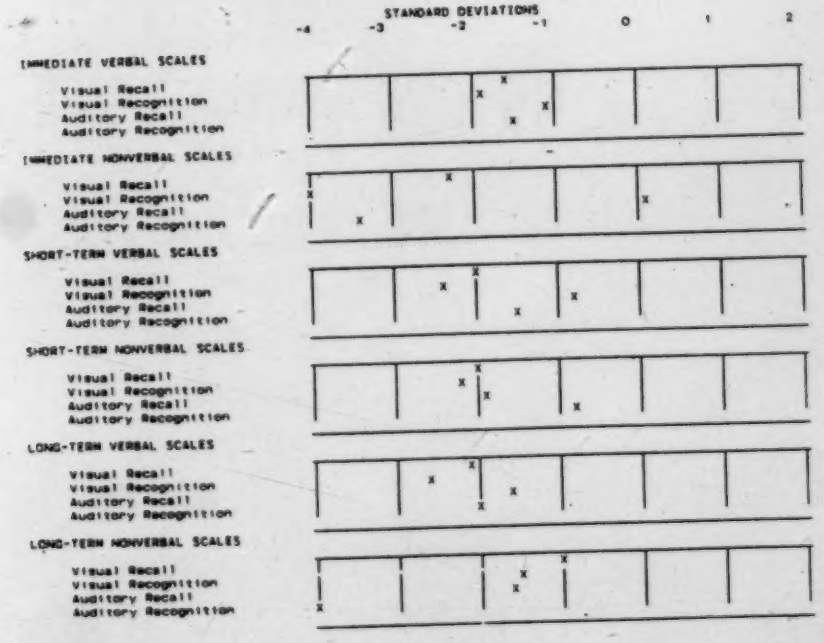

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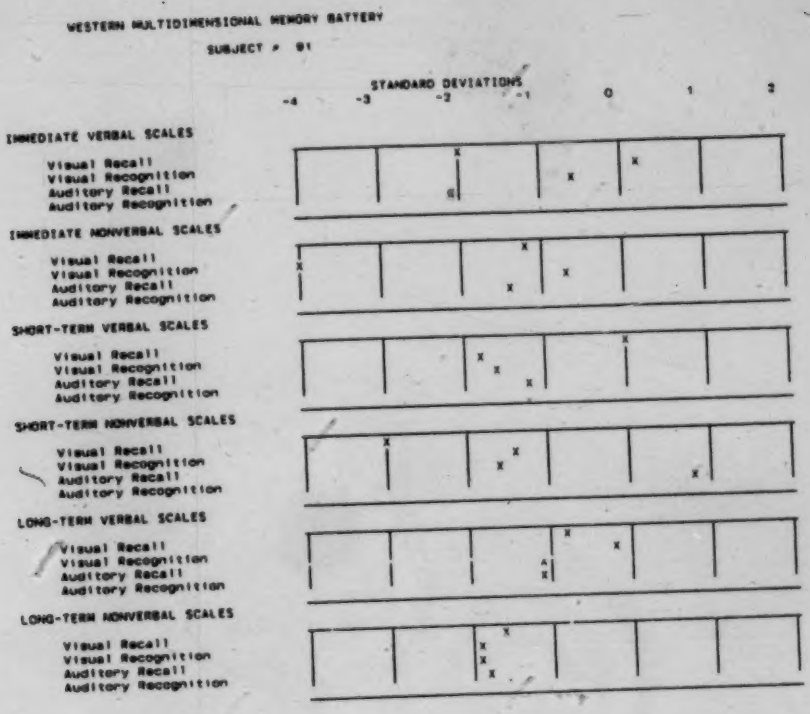
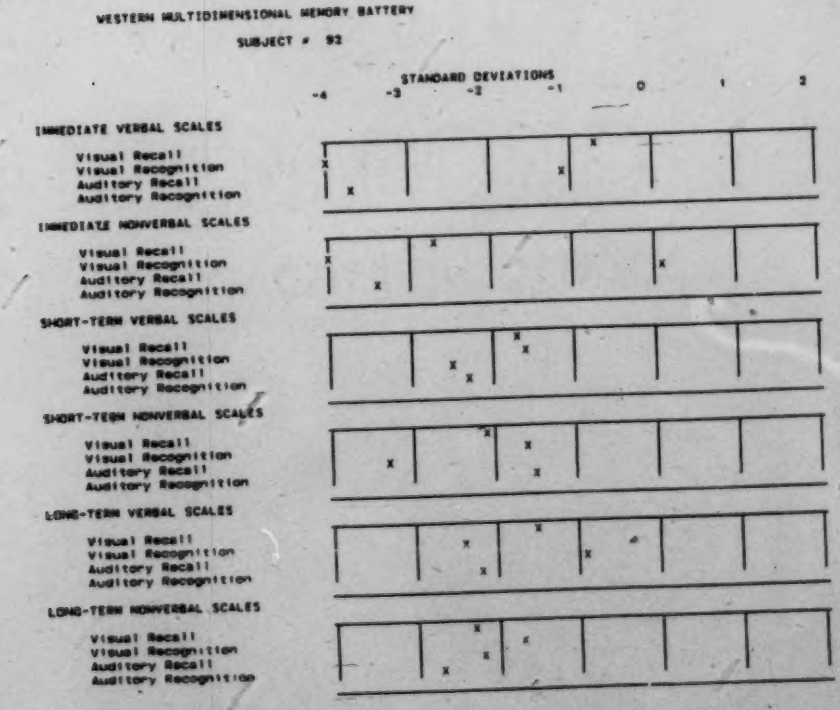


Figure B92.



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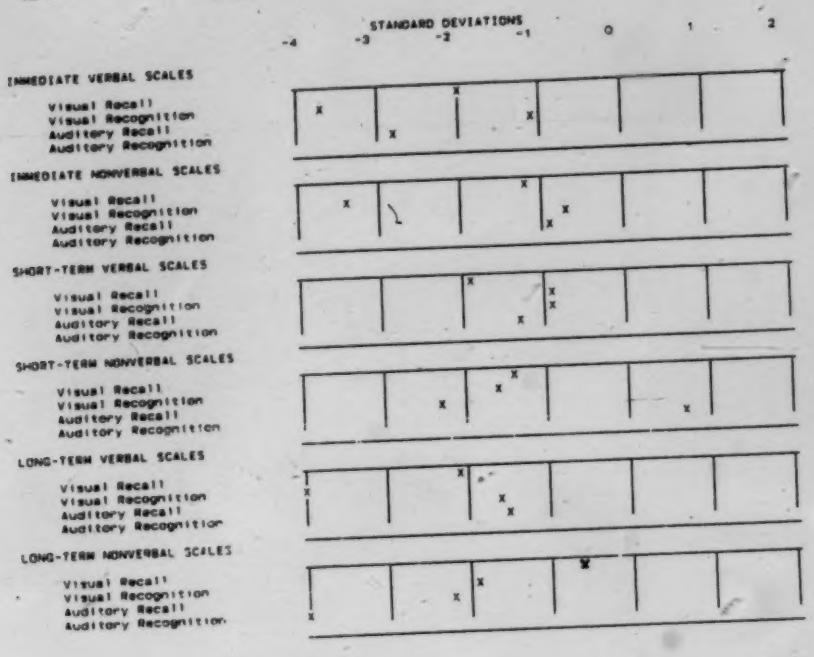

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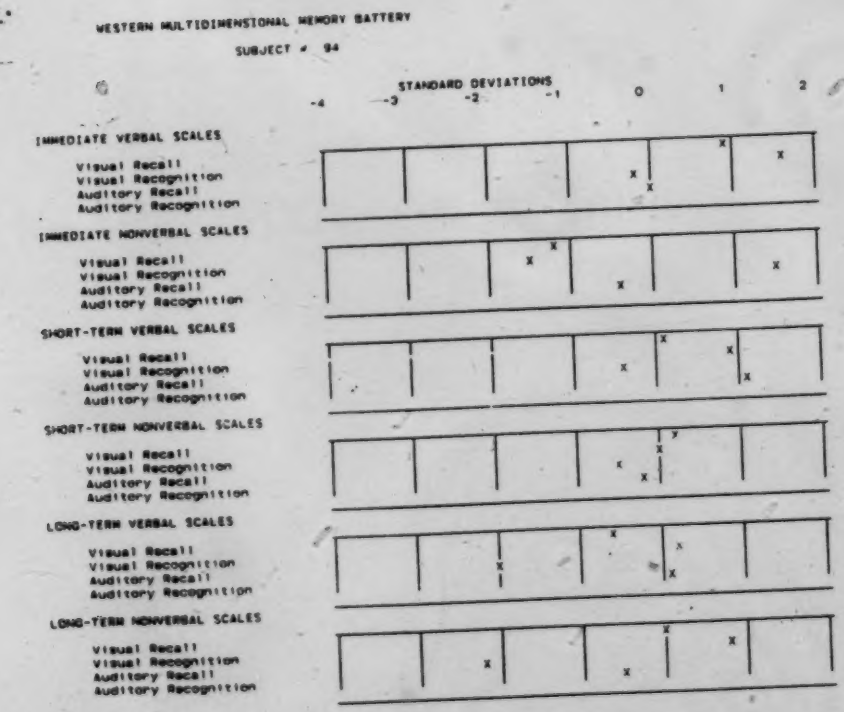

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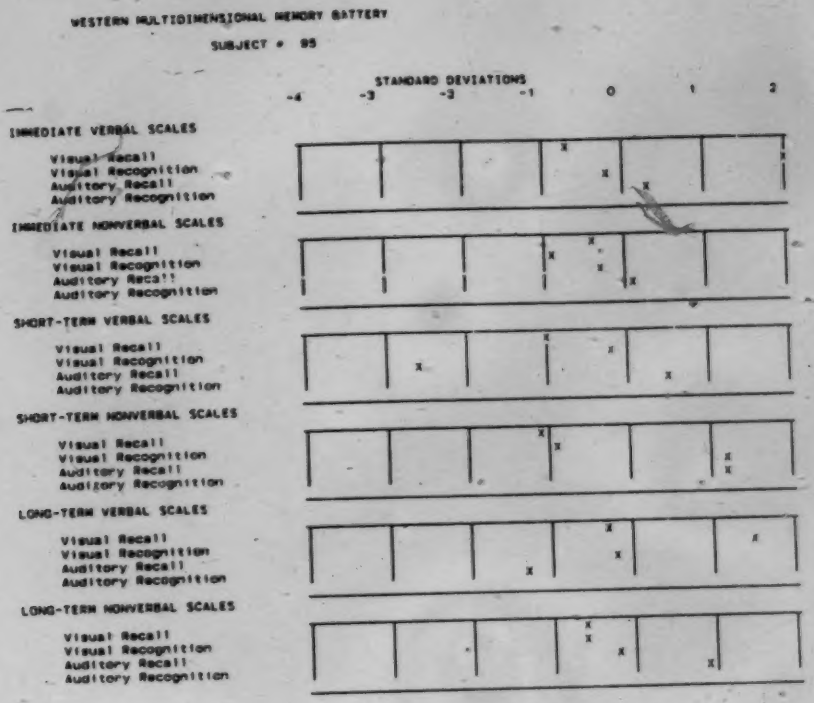
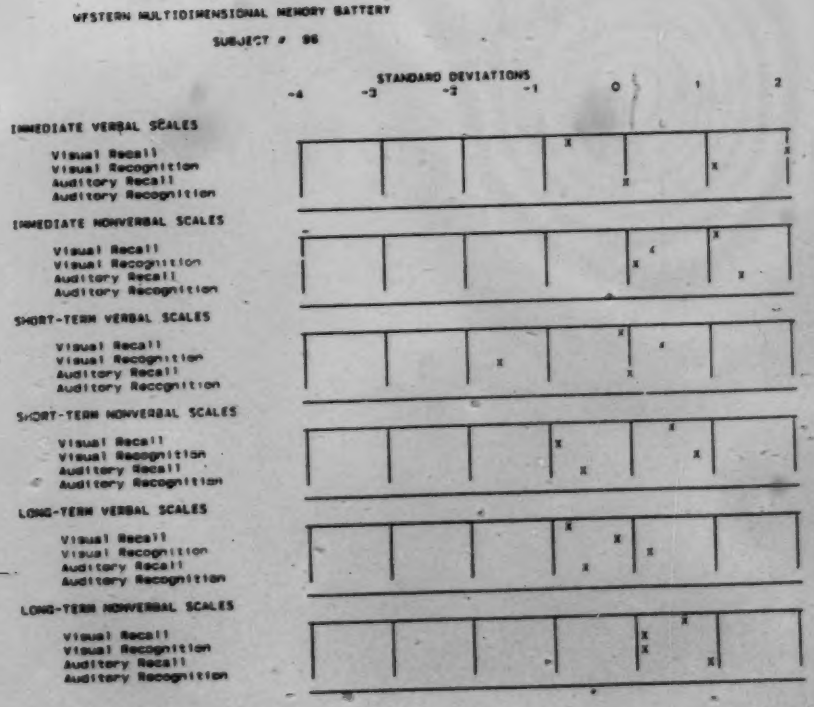


Figure B96.



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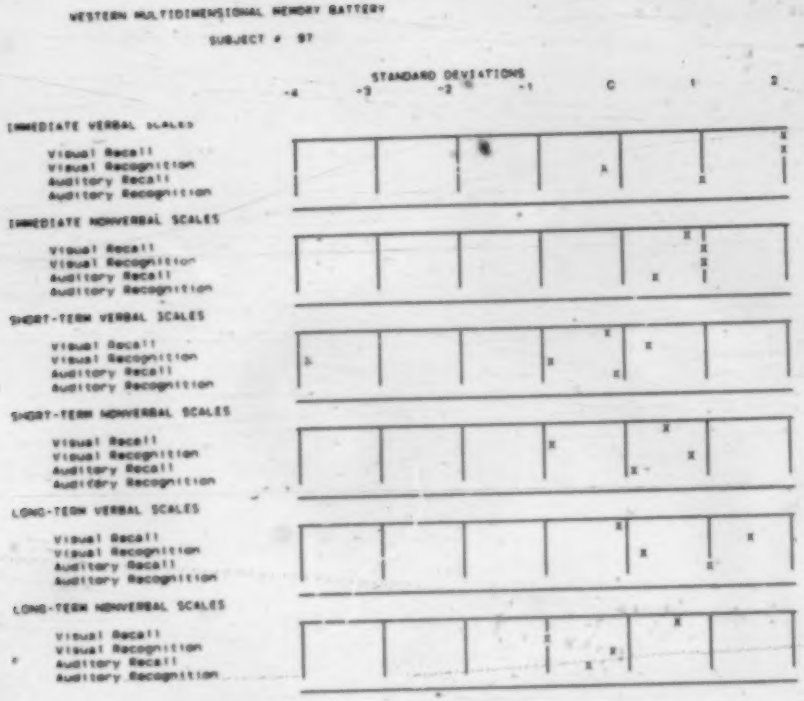

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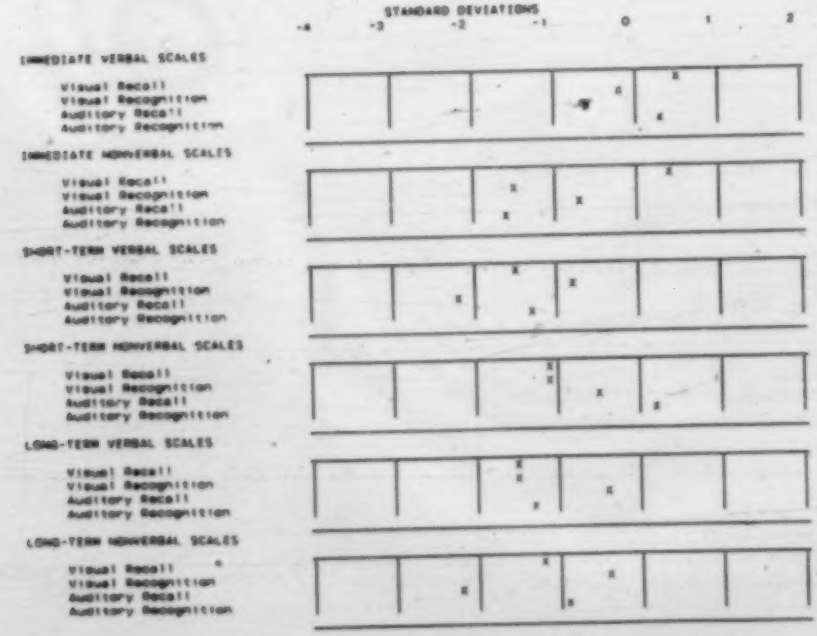

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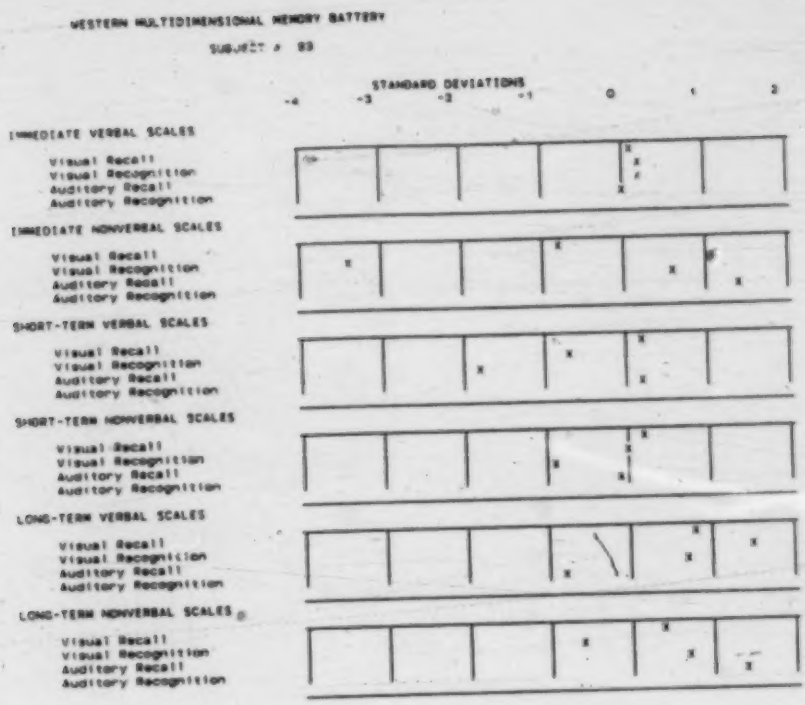
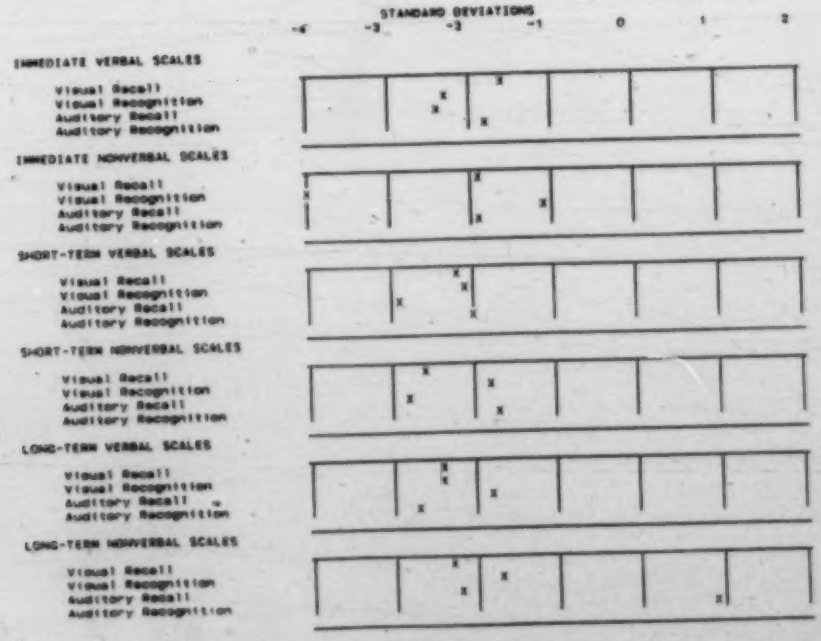


Figure B100.



APPENDIX C

Schumacher Criteria

Appendix A

Schumacher Criteria (1965)

1. Neurological examination reveals objective abnormalities in CNS function.

2. Examination or history indicates involvement of two or more parts of the CNS.

3. CNS disease predominantly reflects white matter involvement.

4. Involvement of CNS follows one or two patterns:

   a. two or more episodes each lasting at least 24 hours and a month or more apart

   b. slow or stepwise progression of signs and symptoms over at least six months.

5. Patients 10 - 50 years old at onset.

6. Signs and symptoms cannot better be explained by other disease process.

APPENDIX D

Kurtzke Expanded Disability Status Scale

Kurtzke Functional Systems Scale

Consent to Participate

Medical Consent to Participate for Hospitalized Patients

Demographic Information Form

I. Disability Status Scale in Multiple Sclerosis (Kurtzke, 1955)

(In parentheses are listed usual equivalents for defects in the functional systems.)

0	Normal neurologic examination (all grade 0 in functional systems)
1	No disability and minimal signs such as Babinski sign or vibratory decrease (grade 1 in functional systems)
2	Minimal disability, for example, slight weakness or mild gait, sensory, visumotor disturbance (1 or 2 functional systems, grade 2)
3	Moderate disability though fully ambulatory (for example, monoparesis, moderate ataxia, or combinations of lesser dysfunctions) (1 or 2 functional systems, grade 3 or several, grade 2)
4	Relatively severe disability though fully ambulatory and able to be self-sufficient and up and about for some twelve hours a day (1 functional system, grade 4, or several, grade 3 or less)
5	Disability severe enough to preclude ability to work a full day without special provisions. Maximal motor function: walking unaided no more than several blocks (1 functional system, grade 5 alone, or combination of lesser grades)
6	Assistance (canes, crutches, or braces) required for walking (combinations with more than 1 system, grade 3 or worse)
7	Restricted to wheelchair but able to wheel self and enter and leave chair alone (combinations with more than 1 system, grade 4 or worse; very rarely pyramidal system, grade 5 alone)
8	Restricted to bed but with effective use of arms (combinations usually grade 4 or above in several functional systems)
9	Totally helpless bed patients (combinations usually grade 4 or above in most functional systems)
10	Death due to multiple sclerosis

II. Functional Systems

a) Pyramidal functions

0 Normal

1 Abnormal signs without disability

2 Minimal disability

3 Mild or moderate paraparesis or hemiparesis; severe monoparesis

4 Marked paraparesis or hemiparesis; moderate quadriparesis; or monoplegia

5 Paraplegia, hemiplegia, or marked quadriparesis

6 Quadriplegia

V Unknown

b) Cerebellar functions

0 Normal

1 Abnormal signs without disability

2 Mild ataxia

3 Moderate truncal or limb ataxia

4 Severe ataxia all limbs

5 Unable to perform coordinated movements due to ataxia

V Unknown

X is used throughout after each number when weakness (grade 3 or more is pyramidal) interferes with testing

c) Brainstem functions

0 Normal

1 Signs only

2 Moderate nystagmus or other mild disability

3 Severe nystagmus, marked extraocular weakness, or moderate disability of other cranial nerves

4 Marked dysarthria or other marked disability

5 Inability to swallow or speak

V Unknown

d) Sensory Functions

0 Normal

1 Vibration or figure-writing decrease in 1 or 2 limbs

2 Position sense decrease 1 or 2 limbs or vibration decrease in 3 or 4 limbs

3 Absence of vibratory sense or severe decrease in position sense or discrimination in 1 or 2 limbs or mild decrease of touch or pain

4 Severe impairment of proprioception in 3 or 4 limbs or at least moderate decrease of touch or pain in at least 1 limb

5 Loss of all modalities of sensation in 1 limb or decreased touch or pain over most of the body

6 Loss of sensation below the head

V Unknown

e) Bowel and bladder functions

0 Normal

1 Mild hesitancy, urgency, or retention

2 Moderate hesitancy, urgency, retention, or rare urinary incontinence

3 Frequent incontinence

4 In need of almost constant catheterization

5 Loss of bowel and bladder function

V Unknown

f) Visual functions

0 Normal

1 Scotoma with visual acuity (corrected) better than 20/30

2 Worse eye with scotoma with maximal visual acuity (corrected) of 20/30 to 20/59

3 Worse eye with large scotoma, or moderate decrease in fields, but with maximal visual acuity (corrected) of 20/60 to 20/99

4 Worse eye with marked decrease of fields and maximal visual acuity (corrected of 20/100 to 20/200; grade 3 plus maximal acuity of better eye of 20/60 or less

5 Worse eye with maximal visual acuity (corrected) less than 20/200; grade 4 plus maximal acuity of better eye of 20/60 or less

6 Grade 5 plus maximal visual acuity of better eye of 20/60 or less

V Unknown

g) Mental functions

0 Normal

1 Mood alteration only

2 Mild decrease in mentation

3 Moderate decrease in mentation

4 Marked decrease in mentation (chronic brain syndrome, moderate)

5 Dementia or chronic brain syndrome--severe or incompetent

V Unknown

h) Other functions

0 Normal

1 Any other findings (specify)

V Unknown

KURTZKE DISABILITY SCALE RATING

FUNCTIONAL SYSTEMS RATING

a) Pyramidal

b) Cerebellar

c) Brainstem

d) Sensory

e) Bowel and bladder

f) Visual

g) Mental

h) Other

CONSENT TO PARTICIPATE

I _____ agree to participate in a study of memory in people with multiple sclerosis. The purpose of the study has been explained to me and I understand that all information will be treated as confidential. The study will consist of a vocabulary test, a memory questionnaire administered in two parts (each taking approximately 2 hours) and a short neurological examination by Dr. K. Warren in the M.S. Clinic, at my convenience.

Date _____ Signed _____

Witness _____

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NEUROLOGIST
432-6296

D. J. CARROLL, M.D., F.R.C.P.(C)
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432-6409

B. L. M. FREMIT, B.SC.P.T.
PHYSIOTHERAPIST
432-8851

P. SHAW, B.A., M.ED.
REHABILITATION PSYCHOLOGIST
432-4739

RESEARCH LABORATORY
432-2043

MULTIPLE SCLEROSIS RESEARCH CLINIC
9-101 CLINICAL SCIENCES BUILDING
THE UNIVERSITY OF ALBERTA
11282 - 84 AVENUE
EDMONTON, ALBERTA
T6G 2G3

September 15, 1983

Dear

We are presently conducting research into memory deficits in patients who are registered with the M.S. Clinic, at the University of Alberta Hospitals. The purpose of the research is to determine the scope of the problem, whether there is a modal pattern of loss and whether it is correlated with time since disease onset, diagnosis, and/or neurological evidence of impairment.

The research will consist of four parts:

1. An initial visit to the subject to explain the research, ask if they are willing to participate, and to administer a vocabulary test.

2. Administration of Part (a) of the Memory Battery. This takes approximately two hours and consists of words, syllables and pictures etc. presented to the subject and later tested for retention.

3. Administration of Part (b) of the Memory Battery, similar to Part (a) but of shorter duration. The test has been broken into two parts, to be administered on two different days, to guard against fatigue in the patient, and will be conducted in the extended care facility.

4. A neurological examination by Dr. K. Warren, Neurologist, Director of the Multiple Sclerosis Clinic at the University of Alberta Hospitals.

The information gained from this research will not be identified by the name of the patient or facility in subsequent publication.

.../2

Your permission to test those patients who have agreed to participate will be much appreciated.

Yours sincerely,

Pat Shaw
Psychologist

Demographic Information

DATE

NAME

SEX

DOB

MARITAL STATUS

YEARS OF EDUCATION

OCCUPATION

LAST EMPLOYED

DIAGNOSIS

YEARS SINCE ONSET

YEARS SINCE DIAGNOSIS

APPENDIX E

Preliminary Analysis

Analysis of Variance Summary - Preliminary Analysis

Effect	MS	f	Df	p
Overall Mean	1598.99	86.22	1, 99	<0.001
Time (Short, Intermediate, Long)	38.43	20.45	2, 98	<0.001
Material (Verbal, Nonverbal)	5.80	4.98	1, 99	<0.050
Reception Mode (Visual, Auditory)	33.08	28.41	1, 99	<0.001
Output Mode (Recall, Recognition)	3.30	2.94	1, 99	<0.100
Time x Material	10.26	5.53	2, 98	<0.010
Time x Reception	0.67	0.50	2, 98	>0.500
Time x Output	25.27	11.25	2, 98	<0.001
Material x Reception	76.57	66.29	1, 99	<0.001
Material x Output	0.03	0.04	1, 99	>0.500
Reception x Output	22.72	51.62	1, 99	<0.001
Time x Material x Reception	0.71	0.06	2, 98	>0.500
Time x Material x Output	7.47	4.97	2, 98	<0.010
Time x Reception x Output	4.71	5.26	2, 98	<0.010
Material x Reception x Output	29.27	29.46	1, 99	<0.001
Time x Material x Reception x Output	11.37	7.90	2, 98	<0.001